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OFFICE OF
COAL
RESEARCH &
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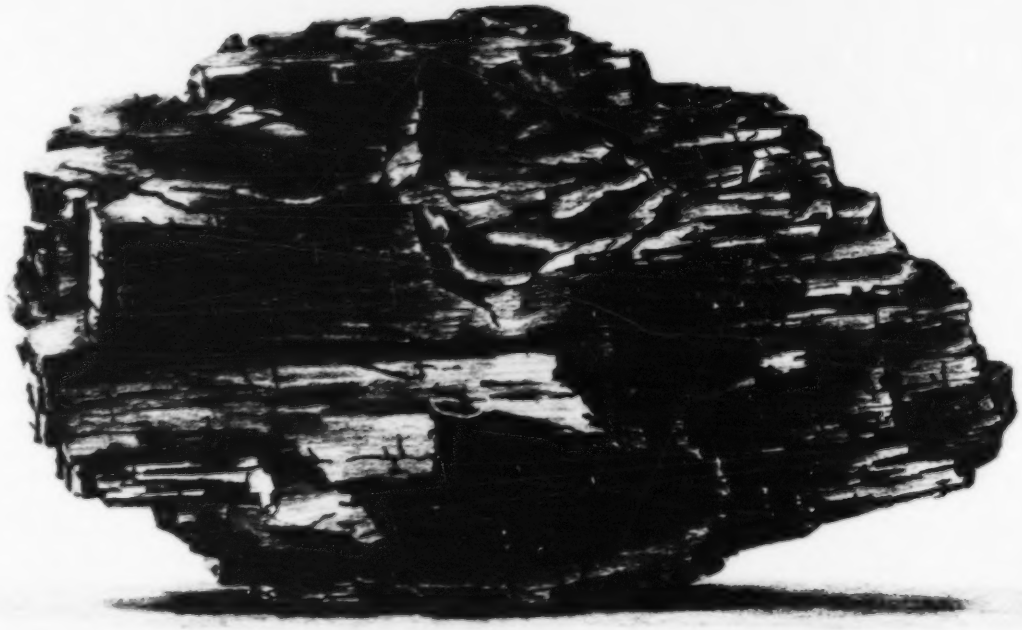

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Introduction

The Alberta Office of Coal Research and Technology was established January 20, 1984, by Ministerial Order under the Department of Energy and Natural Resources Act.

Its purpose is to co-ordinate the Alberta government funding needed to identify, investigate and develop coal-related technologies considered to be commercially important during the next decade. Its goals are:

- to enhance the competitiveness of Alberta's coals in international markets;
- to minimize the environmental impact of the production or use of coal in Alberta; and
- to create new uses for Alberta's coals.

Appointed to the Office are R. Douglas McDonald as Chairman, and Garnet T. Page and Michael A. Ward as Members. T. David Brown represents Energy, Mines and Resources Canada as an observer and participates in project reviews.

Initial funding of $20 million was allocated from the Alberta/Canada Energy Resources Research Fund to provide financial support for research projects.

A successful Alberta Coal Research Strategy depends on the wise collaboration of government, industry and the research community.

Chairman's Report

Alberta's coal industry achieved considerable success during 1988/89. International coal markets became firmer, mainly because steel production increased, particularly in Japan, and demand for electric power rose throughout the Pacific region of Asia. This led to significant increases in Canadian coal exports and better prices, making this the best year for the coal industry since 1980. Overall production and sales of Alberta coals increased by 4.6 and 3.7 million tonnes, respectively, in 1988 versus 1987. Exports of metallurgical coal increased by 39 per cent over the previous year to 5.7 million tonnes. Thermal coal exports increased by 24 per cent to 3.6 million tonnes. Although Alberta coal producers are still receiving relatively low prices for their products, the trend toward higher production and sales is encouraging. While international coal prices increased by approximately seven per cent, these gains were offset by the increased value of the Canadian dollar. Coal use in Alberta increased also, rising by eight per cent to 19.9 million tonnes. This reflected continued growth in electric power demand.

The industry remains optimistic about 1989/90 markets. Concerns are increasing, however, over the lack of public awareness about the importance of coal to economic growth and energy security. This is revealed in the growing public debate about global warming and climate change. The perceived role of coal in this situation is becoming a priority issue for the coal industry world-wide.

Within the coal industry, it is apparent that more companies support the idea that technology development and application have become, and should remain, essential elements of a healthy industry. The recent appointment of a director of research and development by The Coal Association of Canada is significant. The importance of technology development to the industry is also revealed by the willingness of a growing number of companies to participate in joint industry/government research projects. These technologies not only improve productivity, but help create new market opportunities. The Office, therefore, remains committed to working closely with coal producers and users, ensuring the timely development and application of new technology to enhance the competitiveness of Alberta coals in provincial, national or international coal markets.

This year, as in the previous two years, the Office continued to operate under a tight budget. Much has been accomplished nonetheless. Within this fiscal limitation, and in recognition of the current interest in promoting the use of western Canadian coals in Ontario, several projects were launched to help achieve the ultimate goal of reducing the delivered cost of Alberta coal in Ontario. These projects fell within the new Western Coal-To-Ontario Program. It involves projects aimed at improving the energy content of coal and lowering its transportation cost per unit of energy. Associated with these new projects were studies continued from last year pertaining to coal-oil pipelining and coal-water pipelining using existing pipelines. In addition to its focus on transportation-related technology, the Office worked closely with the coal industry and other governments participating in the Coal-to-Ontario initiative to define several research and development projects related to improved coal production technology. This included mining, fine coal processing and recovery, and low-rank coal upgrading.

The other activities of the Office were consolidated this year into three major programs: Strategic Program, Institutional Program and Coal Research Grants Program.

Within the Strategic Program, projects funded jointly with industry are being developed in a manner consistent with industry priorities. This is accomplished through a series of joint industry/government technical committees. These committees comprise representatives of companies and governments who share mutual interests and are willing to fund research and development projects jointly.

By March 31, 1989, functioning technical committees had been organized under the following topics:

- Mining;
- Fine Coal Cleaning;
- Coal Gasification;
- Coal-Fired Steam Generation for Heavy Oil Recovery;
- Sorbent Injection;
- Coal/Heavy Oil Co-processing; and
- Low-Rank Coal Upgrading.

The Institutional Program supports the development and improvement of technical capability at the Alberta Research Council (ARC) and the Coal Mining Research Company (CMRC). This program should assist these organizations in responding to the needs of government and industry. Support from the Office includes funding to permit these organizations to develop or improve their competence in new technologies and remain abreast of developments in particular fields.

The Office continued to encourage scientific excellence in fundamental coal research through the Coal Research Grants Program. This program provides funding to university researchers and has supported 25 projects thus far.

The results of many investigations supported under these four programs are available to industry and other interested parties through technology transfer publications. These are available from the Office or the Alberta Energy/Forestry, Lands and Wildlife information centres.

During 1988/89, 52 projects were under way. This included support for the secretariat functions of two technical committees. Financial contributions by the Office totalled $4 450 788, whereas contributions by industry and other groups totalled $4 551 250 million. The latter represents 51 per cent of total research expenditures for approved projects.

The Office worked closely with the Intergovernmental Secretariat to the Action Committee on Western Canadian Low-Sulphur Coal to Ontario to ensure that Office activities supported the Secretariat's initiatives. Currently, funding is being provided by the Office for several projects, and several technical committees are actively developing projects within this initiative.

Besides the work associated with reducing the delivered costs of Alberta coal in Ontario, program priorities focused on:

- development of coal-fired boilers suitable for producing steam in enhanced heavy oil recovery schemes;
- reduction of sulphur and nitrogen oxides from coal-fired power-generating stations, including investigation of systems that produce less carbon dioxide;
- characterization of the combustion and gasification properties of Alberta coals to assist market development; and
- co-processing of coal and heavy oil to produce liquid transportation fuels.

The Office is encouraging closer collaboration and integration of research activities and administration at the Coal Research Centre, Devon, and with the coal-related activities of the Canada Centre for Mineral and Energy Technology (CANMET) in Ottawa.

Collaboration among research and development organizations in Alberta, throughout Canada and overseas is also encouraged by the Office. Financial support is provided through the Alberta Research Council for collaborative work on liquefaction of Alberta coals involving Canada and Japan. Discussions are under way to include coal gasification studies in this joint program.

With technical assistance by the Alberta Research Council, the Office is participating in an International Energy Agency-sponsored project to investigate the fundamentals of coal combustion.

Another international initiative of the Office, in conjunction with Energy, Mines and Resources Canada, several Canadian companies, one German firm and the Government of the Federal Republic of Germany (FRG), involves investigating the potential of coal-water slurry technology in reducing coal transportation costs. Opportunities to collaborate with the FRG government on coal gasification are being explored.

Day-to-day administration of Office projects is provided by staff of the Alberta Department of Energy, Scientific and Engineering Services and Research Division. Additional assistance and considerable support and co-operation have been provided by the coal industry, the Coal Research Technical Panel, the Interdepartmental Group for Coal Research and The Coal Association of Canada.

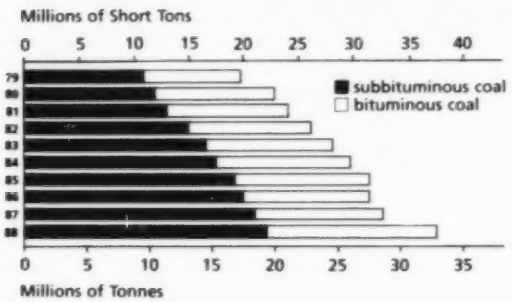
R. Douglas McDonald
Chairman

Background

Alberta's coal industry provided an important energy source during early development of the province, and continued to contribute significant economic activity until about 1950 when the coal market collapsed. In the mid-1960s, a resurgence occurred in the export market for metallurgical coal and in the provincial market for thermal coal. By 1974, annual production had risen to 9.5 million tonnes.

Alberta's raw coal production rose steadily after 1975, reaching 27.7 million tonnes in 1985. It remained at that level in 1986, but has been rising ever since. In 1988, it reached 33.4 million tonnes, a 16 per cent rise over 1987 production.

Raw Coal Production



Today, Alberta is Canada's largest coal-producing province and the second largest coal-consuming province. Alberta's 12 major coal mines produce three types of coal for three different markets. Approximately 2/3 of total production is subbituminous coal produced from plains mines and used for power generation at mine-mouth electricity-generating stations.

High-quality, bituminous metallurgical coal is produced from three mountain coal mines for export to the steel industries in Japan, Korea and Brazil. Low-sulphur, bituminous thermal coal is produced from two mines in the foothills region of Alberta for export to Ontario, Japan and Korea. Also, five small mines in the plains area supply coal for domestic use.

Although the international coal market is still in an oversupply situation at present, several thermal coal mines in the foothills region have been approved for development as export markets warrant. Income earned by Alberta's coal producers is derived from exports of bituminous coals, and from combustion of subbituminous coals by Alberta utility companies which produce more than 91 per cent of Alberta's electricity.

Approximately 2 400 people are directly employed by Alberta's coal producers.

These statistics emphasize some of the benefits and the importance of Alberta's coal industry, but there are other advantages to having a healthy coal industry in the province. For example, coal mines provide a high economic and social return on the land used. Also, the sale of coal to other countries improves Canada's trade balance, contributes to expansion of the provincial transportation network, and fosters growth in the provincial construction industry during periods of expansion. Other direct benefits include financial contributions to the three levels of government, and the purchase of goods and services within Alberta.

It is expected that Alberta's coal industry will continue to supply the fuel that makes low-cost electricity available to all Albertans, as well as encourage the growth of secondary industries, provide a reliable and economic energy source for recovery of the province's heavy oils and bitumen, and make other significant contributions to the province's economic base.

To optimize these benefits, however, coal-exporting companies must continue to capitalize on the upturn in the Japanese economy and improvements in prices paid for Alberta coal. This situation is somewhat hampered by a rising Canadian dollar, however. Nevertheless, Alberta coal producers sold 5.9 million tonnes of metallurgical coal last year. This was an increase of 43 per cent over 1987 sales.

Thermal coal sales rose 18 per cent in 1988 versus 1987, and increased coal sales in Ontario are anticipated as a result of the recommendations of the Action Committee on Western Canadian Low-Sulphur Coal to Ontario.

Today's market conditions make it essential that Alberta coal producers use the most efficient and economical technologies available in coal exploration, production, preparation, upgrading, transportation and marketing. Increasingly, overseas customers are demanding coal and coal products that exhibit specific qualities and behaviour. This means that coal producers must know more about the combustion characteristics of their products. They must also be involved in the development of new technologies such as agglomeration, coal-water fuels and other upgrading processes that will produce coal products tailored to market requirements.

The Alberta coal industry's response to these difficulties and challenges is expressed in the Alberta Coal Research Strategy, published in November 1983, that was the result of extensive discussions among individual companies and the provincial government. Later, the Alberta Office of Coal Research and Technology was established. Subsequently, industry proposals submitted to the Office resulted in research and development projects funded jointly with the Alberta government. Additional support, designed to foster fundamental research beneficial to the coal industry, is provided by the Alberta Office of Coal Research and Technology's Coal Research Grants Program.

This is supplemented by institutional research projects funded by the Office and carried out by the Alberta Research Council and the Coal Mining Research Company. This year, a fourth program called Western Coal-To-Ontario was launched to accommodate projects supported by members of the Action Committee on Western Canadian Low-Sulphur Coal to Ontario.

Another important function provided by the Alberta Office of Coal Research and Technology is the co-ordination of coal research and development activities within Alberta, as well as between Alberta, national and international agencies.

This has led to better integration among the various coal research groups in Alberta. Also, it has resulted in a stronger focus on the needs of industry, and has produced international contacts and greater international co-operation.

The Office has directly influenced research and development activities within Alberta by funding projects jointly with the following: individual coal-producing companies or groups of companies, other government agencies, universities, private research organizations, consultants, utilities, equipment suppliers and agencies in other countries.

The Office is influencing coal research and development elsewhere by participating on various national and international committees, including the International Energy Agency's Working Party for Fossil Fuels and the Canada/Japan Coal Conversion Research and Development Committee.

Coal Research Strategy

Research Rationale

Consistent with the views of the Government of Alberta, the Alberta Office of Coal Research and Technology believes the private sector should take the lead in identifying and managing appropriate research and development programs, as well as implementing and commercializing the results. The role of the Office and other government agencies such as the Alberta Research Council, along with universities and research organizations such as the Coal Mining Research Company, is to support the private sector as necessary to achieve the desired technical results most efficiently.

While there is a recognized need for longer term research and development, as well as basic research to facilitate a better understanding of coal properties and uses, the critical time for commercial expansion and economic development of the province's coal resources will be from 1992 to 1998. During this time, growth in thermal coal use throughout the world is probable, but Alberta's share of the market will be influenced by increased competition from other coal exporters. The extent to which this expansion of thermal coal use can be realized, however, will depend on the prices of other energy supplies, particularly those of natural gas, oil and nuclear power, and the relative social and environmental acceptance of coal versus other fuels.

Towards this end, in 1984 the Alberta Office of Coal Research and Technology identified initial funding through the Alberta/Canada Energy Resources Research Fund of approximately $20 million in support of research, development or demonstration projects. It was anticipated that similar funding would be forthcoming from the private sector. A portion of the funding is being used for longer term or fundamental research directed toward innovative technologies related to production and use of Alberta coals.

Alberta must collaborate closely with research groups elsewhere to ensure that maximum benefit is derived from the total international coal research and development effort, and to define its intermediate- and long-term plans within this context.

In pursuing its objectives, the Alberta Office of Coal Research and Technology works closely with The Coal Association of Canada and the Alberta coal industry to establish research and development priorities. In addition, the Office maintains world-wide contacts with researchers engaged in coal-related studies.

Administrative Framework

The Alberta Office of Coal Research and Technology does not have in-house facilities to carry out research projects. Rather, its primary role is to provide funding for approved coal research projects. Therefore, procedures have been established to ensure sound project management and financial control of approved projects. For each project, specific agreements are signed that define the terms and conditions under which the project will be conducted and funded. These agreements also define the respective rights of new project technology ownership and use.

After proposals have received thorough consideration, those considered to fall within the Alberta Coal Research Strategic Plan are discussed in detail with the applicant, and are often referred in confidence to one or more experts for detailed technical review.

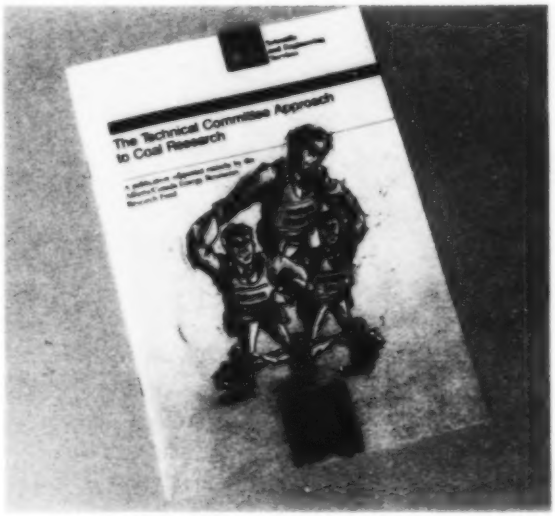
An Alberta government interdepartmental group has been established to review and comment on the implications of the proposed research on their areas of responsibility. This group includes representatives from the Energy Resources Conservation Board and the departments of Forestry, Lands and Wildlife, Economic Development and Trade, Environment, and Community and Occupational Health.

Approval of research proposals by members of the Alberta Office of Coal Research and Technology is based on the results of these reviews, relative funding contributions and the likelihood that proposed research will contribute to achieving the goals of the Alberta Coal Research Strategic Plan. Those projects funded by the Alberta/Canada Energy Resources Research Fund (A/CERRF) are submitted subsequently to the A/CERRF Committee for approval.

Applications received within the scope of the Alberta Coal Research Grants Program are reviewed by the Alberta Office of Coal Research and Technology to ensure they are consistent with the objectives of this program. Applications are then considered in detail by the Coal Research Technical Panel, which makes recommendations to the Office regarding the scientific merit, associated funding, and the extent to which the application should be supported by the Office.

Technical Committees

While the overall objectives of the Alberta Office of Coal Research and Technology are still guided by the Alberta Coal Research Strategic Plan, it is recognized that the process of deciding which projects ought to be initiated requires a flexible administrative structure.



From this, a process has evolved to assist program planning. It involves consultation with industry to identify issues, priorities and potential partners of the Office in new programs and projects. If, as the result of this consultative approach the potential for development of new technology is sufficiently high to attract industry participation and funding, a broad plan for research is developed and a technical committee is established to oversee the program. Typically, the executive of a technical committee comprises co-chairmen representing industry and the Office, a consultant as secretary and a project manager.

Following establishment of a technical committee, project specifications are developed and calls for proposals are issued to qualified firms and research institutions.

After proposals are received and reviewed by the technical committee, working groups are normally formed to manage individual projects. These groups usually comprise companies that are interested in a particular issue and are willing to contribute funds. Working groups pursue problems, enter into contracts, form joint ventures among themselves and seek funding from governments.

Generally, government funding agencies provide 50 to 60 per cent of the funds needed for precommercial research (defined as investigations that precede commercial-scale developments). Occasionally, working groups will proceed without government participation. Funding arrangements are kept flexible to accommodate the needs of participants and the nature of the problem under investigation. When projects are completed, working groups are disbanded.

Full reports on projects are available only to those participants who contribute funds. The question of confidentiality is left to the discretion of working groups. Summaries of results can be released to others, particularly to attract additional participants to later phases of investigation.

Technical committees act as co-ordinating and collaborative agencies. They make recommendations regarding courses of action and whether projects ought to be pursued. Then, any decisions as to project funding are made by senior management of participating companies and agencies.

A technology transfer publication titled The Technical Committee Approach to Coal Research provides more detail. It is available from Alberta Energy/Forestry, Lands and Wildlife information centres.

Research Priorities

Since the Alberta Coal Research Strategy was prepared in 1983, several important events have occurred that could significantly affect Alberta coal producers, particularly those depending on export sales.

For example, Ontario Hydro is considering the use of more low-sulphur western Canadian coals to help meet provincial acid gas emission guidelines and establish a reliable domestic coal supply. This has resulted in a commitment by both industry and government to reduce the delivered cost of western Canadian coal in Ontario.

In Alberta, emphasis is being placed on expanding opportunities to use coal in place of natural gas to generate steam for enhanced oil operations.

World-wide, the development of new coal-use technologies is generating demand for certain types of internationally traded thermal coals. Suppliers are now aware they should be providing thermal coals tailored to these new systems. Success in these markets will depend on having a better understanding of the performance characteristics of coal products under different operating conditions. Coal gasification developments are of particular interest to the Office and Alberta coal producers.

These changes have been influential in bringing about some modifications to the research priorities of the Alberta Office of Coal Research and Technology. Currently, those priorities are as follows:

- to develop and apply technologies that help expand opportunities to use coal in Alberta, particularly for producing and upgrading heavy oil and bitumen. Currently, several projects are under way to encourage the use of coal to displace natural gas for steam raising in enhanced heavy oil schemes;
- to develop and apply technologies that will have a significant effect on reducing the delivered cost of Alberta coal in Ontario markets or those in the Orient. Emphasis is being placed on coal production and transportation costs, as well as improved fine coal processing;
- to develop technology that will lead to new manufacturing opportunities within Alberta; and
- to develop and apply technology that will help establish and/or improve the quality of Alberta coals or coal-derived products, as required for emerging coal utilization technologies in Ontario or the Orient. Processes and technologies include blending, upgrading, gasification and coal-water fuels.

Research and Technology Programs

During 1988/89, the activities of the Alberta Office of Coal Research and Technology were consolidated into four major programs: Western Coal-To-Ontario Program, Strategic Program, Institutional Program and Coal Research Grants Program.

Projects under way in each of the four programs are described in the following section.

Western Coal-To-Ontario Program

Since the mid-1980s, the potential social and economic benefits of using increased amounts of western Canadian coal in Ontario have been investigated and described by various federal/provincial task forces representing the federal government and the governments of Ontario and the western coal-producing provinces. The most recent of these groups, called the Action Committee on Western Canadian Low-Sulphur Coal to Ontario, comprises the Deputy Prime Minister and the premiers of British Columbia, Alberta, Saskatchewan and Ontario. In 1987, this committee created an Intergovernmental Secretariat which consulted with coal producers, transporters and users to develop possible technological, regulatory and policy options that could lower the delivered cost of western Canadian coal in Ontario.

In its November 1987 report to the Action Committee, the Secretariat identified 14 research and development initiatives within four broad categories that should be pursued. They are as follows:

- Mine Production Improvements;
- Coal Product Improvements;
- Transportation Improvements; and
- Fiscal and Regulatory Improvements.

While each of these initiatives will involve co-operation among the member governments and industry, the Alberta government has agreed to take the lead in implementing the following three initiatives:

- Underground Thick Seam Extraction Using the Room and Pillar System of Mining;
- Ash Reduction, Refuse Reprocessing and Fines Processing; and
- Coal-Oil Mixture Slurry Transportation Concept.

Some of these activities and those led by other governments or The Coal Association of Canada are directed by technical committees comprising representatives of interested governments and industries.

Thick Seam Extraction and Continuous Haulage Mining Demonstration

SMOKY RIVER COAL LIMITED, GRANDE CACHE

Considerable reserves of high-quality thermal and metallurgical coal are present in seams more than 3.7 m thick in western Canadian coal mines, but many of these seams are inclined and difficult to mine using surface-extraction methods. This means underground mining techniques must be used, but most are limited to mining only 3 m of any seam. Therefore, large quantities of the coal resource are left unmined.

However, recent developments in machinery design and mining systems suggest that seams up to 6 m thick can be mined successfully, giving rise to higher rates of resource recovery and improvements in productivity and costs.

Consequently, this multi-year project will evaluate new methods of safely removing coal using flexible conveyor train (FCT) technology, 6-m high pillars and ribs, and the suitability of mobile roof support systems in the underground mine. Also, an innovative roof and side bolter will be designed, constructed and tested as an alternative to the current mine access protection methods.

The project is being financed by Smoky River Coal Limited, the Department of Western Economic Diversification and the Alberta Office of Coal Research and Technology.

Low-Rank Coal Upgrading Technical Committee

Within the coal product improvements area of research, the Low-Rank Coal Upgrading Technical Committee was formed this year under the leadership of Saskatchewan Energy and Mines. The committee comprises approximately 20 members representing Alberta and Saskatchewan coal producers, governments and coal research agencies, as well as the

Ontario and federal governments. The principal objective of this group is to formulate a strategy for developing an upgraded product from western Canadian low-rank coals that would be suitable in the Ontario market.

The committee met several times during 1988/89 and agreed that coal drying and stabilizing were of greatest interest to committee members. This, however, overlapped with the interests of the Spontaneous Combustion Technical Committee. Therefore, the activities of the latter committee were incorporated into the Low-Rank Coal Upgrading Technical Committee.

Currently, the committee is supporting:

- tests of ARCO Flux 130 deactivant. This is a method by which a hydrocarbon coating is applied to dried coal to prevent moisture resorption and spontaneous combustion. The coating also limits dust problems during transport and handling;
- the collection of data on the changes to low-rank western Canadian coals during thermal drying/upgrading; and
- the development of a set of stability criteria for dried/upgraded coals.

Fine Coal Cleaning Technical Committee

In recognition of the problems caused by coal fines, a Fine Coal Cleaning Technical Committee[1] was established in 1988 to provide a method for co-ordinating and funding research efforts. This was given impetus by the report of the Intergovernmental Secretariat to the Action Committee on Western Canadian Low Sulphur Coal to Ontario, which recommended that Alberta should take the lead role in initiating research on fine coal cleaning.

The objectives of the committee are:

- to find ways to reduce the delivered cost of coal in Ontario by improving fine coal cleaning while maintaining coal quality at its current level;
- to achieve fine coal recovery so as to satisfy concerns about environmental and resource exploitation efficiency while reducing tailings disposal costs; and
- to develop fine coal products that are acceptable to existing or potential markets.

Topics to be considered for research efforts include:

- Fines Processing
  - Utilization
  - Coal Surface Properties
  - Flotation Techniques
  - Yield Improvement
- Ash Reduction
  - Separation by Size/Specific Gravity
  - Chemical Change/Oxidation/Storage
  - Process Automation
  - Ash Surface Properties
- Refuse Reprocessing
  - Tailings and Reclamation
  - Slack Pile Reclamation
  - Environmental Considerations

Some projects described in this section, plus one project described in the Strategic Research Program (Electrocoagulation) were supported by members of the Fine Coal Cleaning Technical Committee.

[1]Committee members on March 31, 1989 were: Crows Nest Resources Limited, Obed Mountain Coal Company Limited, Gulf Canada Resources Limited, Fording Coal Limited, Luscar Sterco (1977) Ltd., Westar Mining Ltd., Luscar Ltd., Esso Resources Canada Limited, Denison Mines Limited, Smoky River Coal Limited, Gregg River Resources, Quintette Coal Limited, CANMET, Energy, Mines and Resources Canada, British Columbia Mines, Energy and Petroleum Resources, Saskatchewan Energy and Mines, and Alberta Office of Coal Research and Technology, assisted by the Coal Mining Research Company.

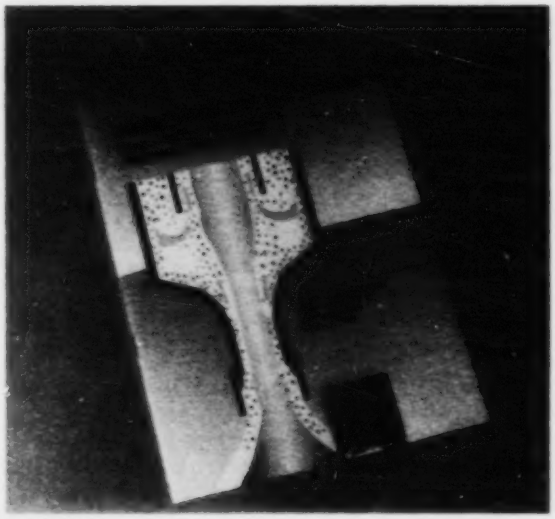
Air-Sparged Hydrocyclone

HYDRO PROCESSING & MINING LTD., CALGARY

As world coal markets become more competitive, the ability to clean the fine components of western coals becomes more important. One fine coal cleaning method that is showing promise relative to conventional flotation methods uses a patented device called an air-sparged hydrocyclone. It was developed at the University of Utah.

In this project, air-sparged hydrocyclones will be installed and operated at four western Canadian coal mines.

Financing is being provided by Hydro Processing & Mining Ltd., participating coal companies, the Department of Western Economic Diversification and the Alberta Office of Coal Research and Technology.



Earlier work on automedium cyclones was described in this technology transfer booklet.

HYDROSIZER for Fine Coal Recovery from Tailings

OBED MOUNTAIN COAL COMPANY LIMITED, CALGARY

Coal-cleaning operations elsewhere have shown that the patented HYDROSIZER device effectively separates low-density, undesirable material from fine coal (0.55 X 0.1 mm) having specific gravity values of less than 1.5. The device, however, has not been tested on western Canadian coals. Consequently, the HYDROSIZER will be assessed for its ability to clean fine coals at a low separating gravity of approximately 1.5. Also, the ease of incorporation of the pilot unit into an existing preparation plant will be evaluated, and the economics of using the device will be determined.

The project is being financed by Obed Mountain Coal Company Limited, the Department of Western Economic Diversification and the Alberta Office of Coal Research and Technology.

Tailings Reclamation

LUSCAR STERCO (1977) LTD., (EDSON) AND
OBED MOUNTAIN COAL COMPANY LIMITED, (HINTON)

All coal preparation plants generate coal refuse known as tailings. Depending on the type of coal being mined, as well as the preparation plant yield and the amount of clay present in the tailings, the disposal of tailings into holding ponds can represent a significant portion of preparation plant operating costs. Various methods for dewatering slurries containing tailings have been tried, including mechanical dewatering using filter presses. In this project, however, an alternative method will be used. It involves dividing a sizeable holding pond into three tiered zones and experimenting with various methods of stabilizing and reclaiming each zone. The upper zone would be returned to forest production, while the middle zone would be left as a grassland area. The lower zone could be reclaimed as a wetland or marsh.

Financial support for this project is being provided by Luscar Sterco (1977) Ltd., Obed Mountain Coal Company Limited, the Department of Western Economic Diversification and the Alberta Office of Coal Research and Technology.

transCOM Co-ordinated Vendor Tests

UNOCAL CANADA LIMITED, CALGARY

It has been estimated that the cost of transporting Alberta coal to Ontario can be reduced if slurries of coal and oil are pumped through existing oil pipelines, rather than being shipped in bulk by rail as is done now.

Last year, in a separate project, a laboratory-scale technical feasibility study was performed to assess the merits of the coal slurry pipeline option for delivering coal to Ontario. A preliminary economic study found that such a system could be viable when the demand for coal at a single power plant in Ontario was 1-2 million tonnes per year.

In an extension of the earlier project, the objective of this project is to scale up the entire chain of preparation, transportation and separation stages and address some potential problems identified in the earlier work.

Thus far, the relative merits of dry versus wet grinding of coal have been investigated, and some agglomeration work was done at the National Research Council on a low-rank coal. It was found that slurries can be prepared readily from coal-hydrocarbon mixtures, and they can be separated successfully. Coal-condensate mixtures produce a clean coal product with good combustion properties that should be acceptable as fuel for enhanced recovery of heavy oil in central Alberta. Coal-oil mixtures produce a coal product with some oil remaining on the coal. Further testing is required to determine its acceptability as a fuel.

Financial support is being provided by Unocal Canada Limited, the Department of Western Economic Diversification, the Ontario Ministry of Energy and the Alberta Office of Coal Research and Technology.

Strategic Program

The Government of Alberta believes that private sector companies should be primarily responsible for ensuring the economic development of the province. Similarly, Alberta's coal industry is expected to take the lead in developing and marketing coal resources, as well as identifying and managing the coal resources needed to improve the industry's competitive position. The role of the Office, other government agencies, universities and research organizations is to support the private sector in achieving appropriate coal-related technological developments.

Several projects have been funded jointly by industry and the Office, with technical support sometimes provided by other research organizations.

Downhole Geophysics

TRANSALTA UTILITIES CORPORATION (CALGARY) AND OTHER PARTICIPANTS[1]

This research project was initiated in 1986 to study the practical application of downhole geophysics to the quantitative determination of geotechnical and hydrological parameters in overburden materials. The objective is to identify and refine methods that will improve the collection of geotechnical and hydrological data for open-pit coal and oil sands mines in western Canada.

Most of the data needed to design and operate a typical open-pit mine currently come from core samples taken from exploration boreholes. These cores are analysed for the various physical characteristics that affect mine design and cost. Core drilling and laboratory analyses are expensive, however, causing mine designs to be based on a limited amount of data.

It is believed that downhole geophysics could provide considerably more information on overburden characteristics at a lower cost. Although the use of instrumentation for downhole geophysical measurement is well established, it remains to be demonstrated that quantitative interpretation of data for physical characteristics can be achieved for Alberta's mining conditions.

Promising geophysical methods were evaluated during earlier phases of this research. Subsequently, some of the participating companies supplied downhole geophysical data and corresponding measurements of geotechnical and hydrological properties to establish a data base from which correlations could be derived. Although some correlations were found, they needed to be strengthened. It was felt that improved data handling, correction and analysis procedures, and expanded data sets were needed.

Recent work on one of the geotechnical data sets demonstrated that improved data correction and analysis procedures are effective for strengthening the correlations. Results for direct shear test parameters, bulk density, Atterberg limits, natural water content and glacially deformed bedrock were particularly encouraging. Deformed and undeformed materials were successfully differentiated using geophysical log data at two sites.

A preliminary evaluation of a full-wave sonic tool was completed. Field trials were conducted for a variety of logging devices, including natural gamma, temperature, several types of resistivity designs and a portable neutron moisture probe.

Publications

TransAlta Utilities Corporation. 1987. Determining Geotechnical and Hydrogeological Parameters Using Downhole Geophysics in the Canadian Plains: Phase I. A Review of Potential Applications.

TransAlta Utilities Corporation. 1988. Determining Geotechnical and Hydrogeological Parameters Using Downhole Geophysics in the Canadian Plains: Phase II. Correlations of Existing Data.

TransAlta Utilities Corporation. 1989. Downhole Geophysics Project Phase 3A Report.

[1]Other participants in Phase II were: Fording Coal Limited, Klohn Leonoff Ltd., Manalta Coal Ltd., Monenco Consultants Limited, Saskatchewan Power Corporation, Suncor Inc., Syncrude Canada Ltd., Terracon Geotechnique Ltd., Alberta Research Council and CANMET. The Alberta Office of Coal Research and Technology was assisted by the Coal Mining Research Company.

Other Phase III participants were: Manalta Coal Ltd., Monenco Consultants Limited, Saskatchewan Power Corporation, Syncrude Canada Ltd., BPB Wireline Services Limited, N. Wade Holdings, Alberta Research Council, Coal Mining Research Company (which acted as Project Manager) and the Alberta Office of Coal Research and Technology. Expert advice was provided by W.S. Keys of Geokeys and C.J. Mwenifumbo of the Geological Survey of Canada.

Geophysical logging of a drillhole at the Highvale mine.

Mining Technical Committee

In recent years, several research organizations, companies and funding agencies in Alberta have been involved in geomechanical studies of Alberta's resources, including coal, but these investigations have been carried out independently of each other. Therefore, in May 1988, the Mining Technical Committee was formed to co-ordinate research and development funding among federal and provincial governments and private organizations in the area of coal production technology.

The technical committee comprises representatives of coal producers, engineering firms, geophysical instrument manufacturers, research and development agencies, and the Alberta and federal governments.

The committee identified the following priority areas for investigation:

- Mining costs;
- Optimal recovery of resources; and
- Product quality.

Also, the committee is co-ordinating mining technology components of research associated with reducing the delivered cost of western Canadian coal in Ontario.

This year, the Mining Technical Committee initiated the following project:

- Surface Geophysical Techniques for Foothills and Mountain Coalfield Exploration.

Surface Geophysical Techniques for Foothills and Mountain Coalfield Exploration

ESSO RESOURCES CANADA LIMITED (CALGARY)
AND OTHER PARTICIPANTS[1]

In an earlier project (Surface Geophysical Coal Exploration, completed in 1986/87), the value of high-resolution geophysical methods was demonstrated at three coal-mines in the plains region.

Based on the promising results at these mines, it was decided that high-resolution geophysical methods should be tried at sites where more complex geological conditions exist. While 50 years experience with surface geophysical methods in petroleum and metal exploration suggests that suitable measurement technology is available, the economic value of these techniques in coal exploration is still uncertain. For example, it is known that high-resolution geophysical methods demand better-than-standard topographical surveys. Also, steeply dipping beds must be mapped with a dense network of measurement points. The large volume of data collected from such a program demands sophisticated data management and processing techniques. Therefore, if these methods are to be useful to Alberta's coal industry, they must be at least as effective as, and less costly than, conventional drilling programs designed to obtain an equivalent amount of information.

In this three-year project, increasingly complex geological settings will be investigated to accommodate the variety of geology and topography found in Alberta. The studies will cover features such as folding, faulting, dipping strata and tectonically thickened coal under topography that varies from flat to rugged.

Seismic line truck at the Smoky River coal mine.

During 1988/89, seismic lines were run at the Smoky River and Coal Valley mines. The results indicated that measurement of reflection seismic profiles of subsurface characteristics in geologically complex settings is useful. The patterns observed from the reflection seismic data seem to be consistent with the known stratigraphy and geological structure interpreted between the exploratory drill holes. More interpretation will be possible when sonic log data have been received from both test sites.

[1]Other participants were: Crows Nest Resources Limited, Manalta Coal Ltd., Smoky River Coal Limited, Quintette Coal Limited and Luscar Sterco (1977) Ltd. The project is managed by the Coal Mining Research Company.

Electrocoagulation

LUSCAR STERCO (1977) LTD. (EDSON)
AND OTHER PARTICIPANTS[2]

The clay and shale particles suspended in process water after coals have been washed are usually removed in mechanical clarifiers to which chemical coagulants have been added. These coagulants, however, are expensive. An alternative is to use a process called electrocoagulation. In a trial at Luscar Sterco's Coal Valley mine, the process performed well, but it could not compensate for changes in clay chemistry.

Subsequently, a project was initiated this year, involving bench-scale electrocoagulation testing by CANMET at the Coal Research Centre, Devon. The objective was to understand better the factors contributing to the performance of the process and to devise methods of controlling them. At year-end, more than 30 test runs had been completed and several observations had been made. For example, it was concluded that the settling rates of plant thickener overflow water were a function of the following: certain characteristics of the electric current; water pH; conductivity of the water; and the time that water is in contact with the electrocoagulation process cell.

[2]Other participants were: Obed Mountain Coal Company Limited and CANMET.

Coal Beneficiation Process

GULF CANADA RESOURCES LIMITED AND UNOCAL CANADA LIMITED, CALGARY

In earlier phases of this project, a process was developed to upgrade the energy content of low-rank coals and make them suitable for shipping. This was done by treating the coal with a low-cost, residual petroleum product derived from heavy oils and bitumen. This leaves a coating on each dried coal particle, reducing coal dust and improving the coal handling properties. Typically, the treated coal has a calorific value of 6 150 kcal/kg, eight per cent moisture and a dustiness index of four.

During 1986/87, a pilot plant located at the Obed Mountain Coal Company mine was used to produce beneficiated coal at production rates of up to 100 tonnes an hour. When the coal was stockpiled, however, it experienced autogenous heating.

Subsequent investigation revealed that this storage instability was apparently caused by large differences in equilibrium and residual moisture levels. Laboratory evaluations of moisture and oxygen sorption confirmed that the upgraded product is more reactive than the parent coal, and a stabilizing process or agent would be needed to make the process commercially viable.

Last year, optimized process conditions were established to satisfy a set of 96-hour heating and oxygen adsorption criteria. Bench-scale mixing equipment was modified to allow increased residence time, product cooling, improved feed capacity and installation of monitoring equipment. Two tonnes of beneficiated product were stockpiled and tested for stability.

This year, the effect of primary process variables such as temperature, residuum content and residence time was studied. Temperature was found to be the most important factor in reducing the equilibrium moisture. Some secondary process variables were studied, too. The knowledge learned in these tests was used to develop a two-stage, continuous pilot plant. It was used to test certain process variables on a larger scale and produce sufficient quantities of treated coal for stability testing and stockpile monitoring. It was found that the upgraded product remained less stable than the untreated feed coal.

It was concluded that the Gulf Canada Beneficiation Process offers great potential for thermal coal upgrading. Even though product stability is a concern, stockpile monitoring showed that a rapid oxidation period was followed by a period of temperature stability. This suggested that stockpile management was a likely solution to the instability problem.

Coal Agglomeration Process Development

ALBERTA RESEARCH COUNCIL, DEVON

For the past six years, researchers at the Alberta Research Council, with initial funding from the Office and subsequent funding from the Electric Power Research Institute and other sources, have been developing a method for upgrading low-rank coal, involving a process called oil agglomeration. By mixing heavy oil or bitumen with coal slurries under controlled conditions, large particles called agglomerates are formed from which much of the undesirable mineral matter present in the original coal has been removed and transferred to the water. This results in products having a higher energy content and lower ash than the parent coals from which they are derived. Subsequent combustion testing showed that agglomerates formed from subbituminous coals displayed excellent combustion characteristics. These results demonstrated that oil agglomeration is a promising upgrading method.

The initial technology has evolved into two processes; AGLOFLOAT, which involves agglomeration followed by froth flotation, and AGFLOTHERM, which includes a thermal treatment step.

Last year, a consortium[1] of 22 companies and institutions began to provide funding for a pilot-scale evaluation of the processes. A continuous 6-tonne-a-day (250 kg/h) pilot plant was built and a continuous oil recovery unit was designed. This equipment will be used to evaluate the agglomeration potential of coal samples provided by members of the consortium, and provide data to be used in calculating the process economics of a commercial-scale plant.

This year, the pilot plant was commissioned, but additional modifications to the oil recovery facility were required. Experiments concentrated on applications of the agglomeration technology to upgrade low-rank coals, remove pyrite from bituminous coals and clean tarry soils surrounding gas plants.

Thus far, experiments have shown that fuel made by agglomerating low-rank coals contains 35 to 45 per cent more heating value than the original coals.

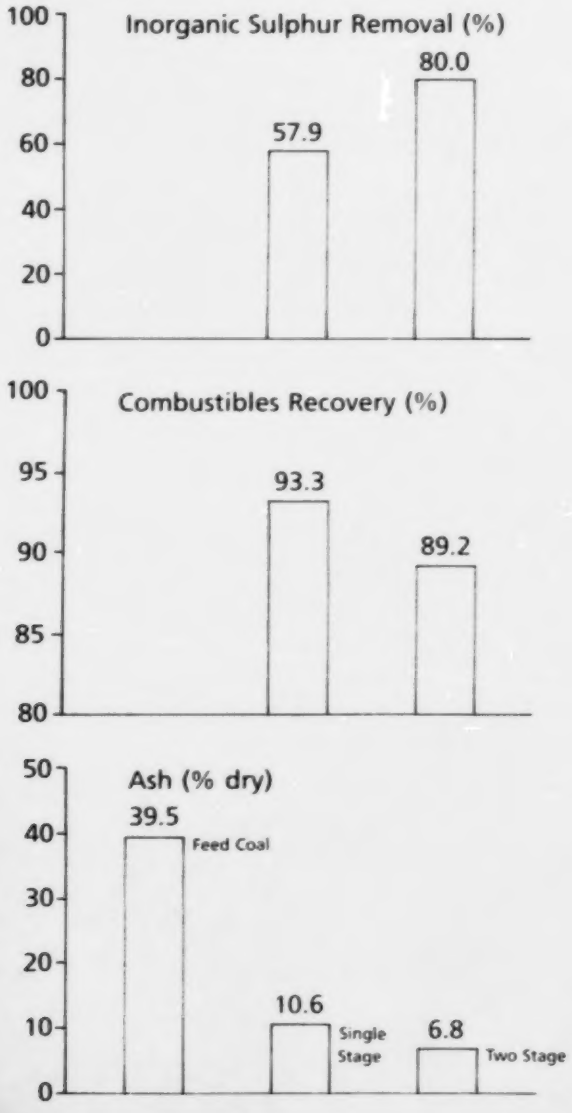
When agglomeration was used to treat coals containing pyritic (organic) sulphur, it was found that the pyrite content of the resulting

[1]The consortium includes: the Electric Power Research Institute, American utility companies, state and federal governments, Canadian oil firms, coal companies, provincial governments, utility companies and the Alberta Office of Coal Research and Technology.

agglomerates was 80 to 90 per cent lower than in the original coal, and more than 90 per cent of the combustible matter was recovered in the agglomerates. This process is regarded as an improvement over other coal-cleaning technologies.

Also, agglomeration was used succesfully to treat tar-contaminated soils. Virtually all of the organic material in the tarry soils was transferred to the agglomerates. Preliminary estimates indicated that a contaminated gas plant site could be cleaned for $40 to $60 a tonne, versus $300 to $1 000 a tonne for incineration.

Cleaning of a High-Volatile Bituminous Coal by AGLOFLOAT Process



Spontaneous Combustion Technical Committee

A Spontaneous Combustion Technical Committee was formed in 1987/88. It had three objectives pertaining to cleaned coal:

- establish thermal stability criteria;
- establish a stability monitoring protocol; and
- establish a method of predicting stockpile behaviour over time.

During 1988/89, some members of the committee funded an investigation concerning the spontaneous combustion of thermally treated coals. (See following project description.)

At year-end, it was decided to incorporate the activities of the committee into the Low-Rank Coal Upgrading Committee.

Committee members on March 31, 1989 were: Obed Mountain Coal Company Limited, Gulf Canada Resources Limited., Saskatchewan Energy and Mines and the Alberta Office of Coal Research and Technology, assisted by the Alberta Research Council and the Coal Mining Research Company. CANMET also participated in the work of the Committee.

Spontaneous Combustion of Thermally Treated Coals

UNOCAL CANADA LIMITED AND GULF CANADA RESOURCES LIMITED, CALGARY

In 1988, some members of the Spontaneous Combustion Technical Committee sponsored a review of literature on the chemistry of spontaneous combustion, with particular emphasis on thermally treated coals. This is especially relevant to low-rank western Canadian coals because they must be thermally dried to reduce their delivered cost per unit of energy in distant markets such as Ontario and Pacific Rim countries. However, thermal drying makes these coals more susceptible to spontaneous combustion.

The study, performed by the Coal Mining Research Company in concert with Bio-Chem Consulting Ltd., the Alberta Research Council and CANMET found that properties of coal are changed by thermal treatment in a vacuum or air, or in an inert atmosphere. This is caused by changes in the surface chemistry and the porous structure of coal. It is believed that thermal drying causes polar groups such as carboxyl (–COOH) or phenol (–OH) to form at the coal surface. These groups cause an increase in the moisture retention capacity of coal, expressed as an increase in the equilibrium moisture content. Because the absorption of moisture is thought to be a key step toward spontaneous combustion, it follows that any thermal drying process that causes the formation of polar groups probably will lead to an increase in the equilibrium moisture content and an increased likelihood that spontaneous combustion will occur. As moisture is absorbed, heat (called the heat of wetting) is generated. This enhances the reaction of oxygen with the polar groups to form peroxygen groups. The latter are highly reactive and decompose readily to form free radicals. As the peroxygen groups decompose, more heat is generated. If the heat cannot be dissipated, spontaneous combustion can occur.

This characteristic is further emphasized in the case of low-rank coals because their pore surface area tends to increase when they are dried. Therefore, it was concluded that, with respect to spontaneous combustion, low-rank coals should not be dried to less than their equilibrium moisture content.

In reviewing current methods of testing the spontaneous combustion susceptibility of coals, it was concluded that internationally accepted standard test methods do not exist. It was further concluded that:

- warm or hot coal should be cooled before being stockpiled or placed in a silo; and
- treating a coal to reduce the heat of wetting is as important as treating it to inhibit oxidation.

Publication

Coal Mining Research Company, Bio-Chem Consulting Ltd., Alberta Research Council and CANMET. 1989. Spontaneous Combustion of Thermally Treated Coals. Prepared for Spontaneous Combustion Technical Committee.

Agglomeration of Coking Coal

SMOKY RIVER COAL LIMITED, GRANDE CACHE

Metallurgical coal currently being mined at Smoky River Coal Limited contains 40 per cent fines. Furthermore, coals expected to be mined in the future have a fines content as high as 50 per cent. While froth flotation is being used to recover some of the fines, this circuit currently limits the capacity of the plant. The recovered product can be dusty and difficult to handle.

Consequently, the company experimented with an oil agglomeration process (developed by the National Research Council) as a fines-recovery method. In laboratory tests, it was found that recovery rates were higher than for froth flotation, and the product appeared to have improved handling characteristics.

Subsequently, the company and the National Research Council (NRC) decided to evaluate the potential of the NRC oil agglomeration process using the NRC mobile pilot plant at the mine site.

Two different coal feeds were evaluated in these tests. One was the -100 mesh raw coal feed to the existing flotation circuit that comprises approximately 18 per cent of total plant feed. The second was the -28 mesh thickener underflow containing typically 40 per cent ash.

Up to 90 per cent yields of coal were obtained from the -100 mesh feed, using oil concentrations ranging from 0.7 to 12 per cent. Dustiness was improved, while both the coking properties and handling characteristics were unaffected. Up to 61 per cent of the coal from the thickener underflow was recovered. With this material, ash content was reduced from 41 to 20 per cent.

An economic analysis revealed that oil agglomeration was somewhat more expensive than using conventional froth flotation, but agglomeration could become competitive if the amount of added oil can be kept at or below one per cent by weight, or if capital costs for agglomeration facilities can be reduced.

International Energy Agency Coal Combustion Science

NETHERLANDS ENERGY RESEARCH FOUNDATION
ECN, PETTEN

Annex II of the International Energy Agency Combustion Science Research Program involves fundamental studies and a series of investigations using semi-industrial scale coal burners to advance the science of pulverized coal combustion and minimize adverse environmental effects. Facilities of the International Flame Research Foundation (IFRF) at IJmuiden, The Netherlands, are being used.

The principal objective is to provide information that can be used to design burners capable of using a wide range of coals and producing flames having acceptable combustion characteristics, while generating few atmospheric pollutants.

The Annex II studies are jointly funded by Canada, The Netherlands and the Federal Republic of Germany. Since 1985, the Canadian contribution has been divided among CANMET, the Canadian Electrical Association and the Alberta Office of Coal Research and Technology.

Within the research program, the following mechanisms are being investigated: nitrogen oxides (NO_x) formation during pulverized coal combustion and opportunities for their reduction through staged combustion; sulphur oxides (SO_x) formation and reduction by the use of direct sorbent injection; transformation of mineral matter during combustion in relation to combustion system slagging, fouling and fly ash emissions; and combustion of various types of coal from several sources. Through the study, methods of predicting flame characteristics are also being developed.

Two air-staging methods were studied extensively: an aerodynamically air-staged burner (AASB) and an air-staged precombustor burner (ASPB). All experiments with these burners were conducted using high-volatile and medium-volatile bituminous coals, including some from the Coal Valley mine to study the effect of scaleup at 1, 2.5 and 4 MW. Studies thus far have shown that both coal quality and burner scale affect the level of NO_x emissions. NO_x levels decrease with increasing burner size. Also, a trade-off between NO_x reduction and carbon burnout occurred. The best performance for AASB was a NO_x concentration of 240 parts per million (ppm) in air emissions, with a 98.5 per cent burnout. This occurred in the absence of excess oxygen. In the case of ASPB, NO_x emissions were 250 ppm at a carbon burnout of 98.5 per cent.

A second approach to NO_x reduction is re-burning or fuel staging. This involves using overfire fuel to create a fuel-rich zone following primary combustion. This year, a literature study revealed that fuel staging is not well understood, and laboratory studies should be undertaken. A series of experiments was conducted to study the effects of coal type and several process parameters on NO_x reduction. Coal from the Obed Mountain mine was included in these studies.

Sulphur dioxide reduction by in-furnace sorbent injection was studied in an isothermal, plug-flow reactor. Calcium hydroxide was found to be the best reagent, and the best results were achieved when furnace temperature was in the 900 to 1 100°C range, and the sorbent was introduced by way of tertiary air.

Influence of Burner Settings on NO_x Production for (AASB) Aerodynamically Air Staged Burner.

High NO_x Conditions for AASB.

Low NO_x Conditions for AASB.

A coal characterization protocol for fuel evaluation and burner design was developed using testing techniques for combustion performance, chemical and mineral composition, maceral composition and reactivity. Coals from the Highvale and Coal Valley mines were included in these studies. Char combustion and pyrolysis behaviour were characterized, and simple models were created to predict the performance of various coals. These models, which included predictions about the heat content of volatile matter, carbon burnout and the abundance of NO_x-forming species, were used to rank the combustion performance of coals for any specified combustion environment.

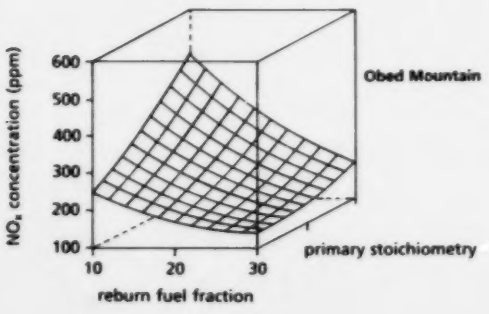
Algorithms used to simulate and predict turbulent fluid flow were used to develop flame models for isothermal swirling flows near burner nozzles. Flow fields and gas temperatures can be modelled reliably, but predictions about gas composition need further refinement. Achieving accuracy of predictions in the near-burner field is the primary objective of these studies.

In October 1988, Great Britain joined The Netherlands, the Federal Republic of Germany and Canada in an extension to the International Energy Agency Annex II coal combustion studies at IFRF.

The primary focus of this work will be to gain a better understanding of the influence of coal characteristics on emission levels, using the air-staging and fuel-staging processes being developed at IFRF. This research will include the effects of fuel/air mixing and coal blending. Also, mathematical modelling will be used to predict temperature and gas concentrations in the "near-burner" zone. As in previous work, one objective is to include Alberta coals in the test program.

Thus far, one fuel-staging trial at a semi-industrial scale was carried out to study the effect of mixing on NO_x reduction. Also, recent numerical simulations of the "near-burner" zone have shown exceptional accuracy in predicting temperature and gas composition.

Effect of Reburn Fuel Fraction and Primary Stoichiometry on NO_x Concentration



Publications

Knill, K.J., N. Kimura and J.P. Smart. Effect of Coal Particle Size and Gun Design on NO_x Reduction Using an Aerodynamically Air Staged Burner: Report on the CC 2-2 Trials. IFRF Document No. F 088/a/6.

Knill, K.J. A Review of Fuel Staging in Pulverized Coal Combustion Systems. IFRF Document No. G 13/a/3.

Knill, K.J., J.S.A. Dekker and M.E. Morgan. Evaluation of the Effect of Process Variables on NO_x and Nitrogen Species Reduction. IFRF Document No. F 37/a/20.

Morgan, M.E. and J.S.A. Dekker. Characterization of the Combustion Performance of a Suite of Pulverised Coals: Report on the CC 1 Trials. IFRF Document No. F 188/a/4.

Smart, J.P., N. Kimura and K.J. Knill. Evaluation of Residence Time and Temperature Distribution in IFRF Furnace #1: Report on the CC 2-1 Investigation. IFRF Document No. F 088/a/5.

Visser, B.M. and R. Weber. Computations of Swirling Pulverized Coal Flames: Report on the MMF 1-2 and MMF 1-3 Investigations. IFRF Document No. F 336/a/11.

Coal-Fired Steam Generation for Heavy Oil Recovery Technical Committee

In 1985/86, the Office and several companies financed a study entitled Fuel Options for Enhanced Hydrocarbon Recovery. The investigation concluded that it was cost-effective for oil companies to use coal instead of natural gas to generate steam needed for enhanced recovery of heavy oil. The study also noted that to use coal successfully in heavy oil recovery schemes, a specially designed, pulverized coal-fired boiler was needed.

Subsequently, the Coal-Fired Steam Generation for Heavy Oil Recovery Technical Committee[1] was formed. It proposed a four-stage development program as the next step in using coal for heavy oil recovery. In the first stage of the program, two boiler manufacturers proposed designs for an innovative coal-fired steam generator. In the second stage, the boiler manufacturers were asked to proceed with engineering designs. One design by Combustion Engineering was prepared this year and is described in the project Coal-Fired Steam Injection Boiler. Concurrently, the committee agreed to investigate the suitability of using the Low NO_x/SO_x Burner (LNSB) system being developed by TransAlta Resources Investment Corporation. This led to two projects this year: Application of the LNS Burner to an Oil Field Steam Generator, and LNSB Steam Generator Demonstration.

In the third stage of the program, begun last year, technologies are being investigated to allow use of the most practicable emission-control systems on the burners now being developed.

Subsequent phases of research planned by the Coal-Fired Steam Generation for Heavy Oil Recovery Technical Committee will include some testing of fuels, during which a range of Alberta coals will be tested to allow combustion performance and emission generation to be predicted when these coals are burned in either of the two boilers now being designed.

Also, alternative coal transportation and handling methods are to be evaluated to achieve the best conditions of economics and logistics, with minimum environmental disruption.

Results from the fuel testing component should allow bottom ash and fly ash characteristics to be predicted. This will lead to an evaluation of ash disposal/use alternatives.

The prototype unit proposed for this program will be located and tested in the field. Its exact location will be decided later.

As required, the general public, as well as coal companies and the petroleum industry, will be kept informed as the program progresses.

This development program is anticipated to cost over $10 million. The potential benefits, however, could be several times this amount in terms of domestic coal sales and lower steam production costs.

An Office publication, Opportunities to Use Coal in Enhanced Oil Recovery, is available from the Alberta Energy/Forestry, Lands and Wildlife information centres (see page 60).

[1]Committee members on March 31, 1989 were: Esso Resources Canada Limited, Fording Coal Limited, Luscar Ltd., TransAlta Utilities Corporation, Alberta Power Limited, Shell Canada Limited, Unocal Canada Limited, Alberta Office of Coal Research and Technology and other observers. Delta Projects Inc. provides co-ordination and promotional services to the committee.

Sorbent Injection Technical Committee

Although the sulphur content of some Alberta subbituminous coals is sufficiently low that current, new-source emission regulations can be met when coals are burned without sulphur oxide emission control, it was recognized that this does not apply to all Alberta subbituminous coals. Therefore, some degree of flue gas clean-up or control will be required to satisfy existing regulations and meet even more stringent guidelines that might be introduced later for emissions of SO_x and NO_x.

Last year, a study of several in-furnace and post-combustion emission-control technologies was undertaken.

It was concluded that the most cost-effective approach to emission control would be to use in-furnace technology as much as possible, and supplement it with post-combustion control if emission standards become even more stringent in the future. Depending on coal quality, it was predicted that NO_x and SO_x emissions would range from 50 to 100 per cent of currently regulated limits for new coal-fired sources using in-furnace technology.

For the present, it was recommended that a combination of furnace sorbent injection and multi-stage burners be used. Several add-on technologies were suggested in the event of more stringent standards.

Subsequently, the Sorbent Injection Technical Committee[1] was established to pursue investigations involving the injection of alkali metal sorbents into coal-fired furnaces to capture acid-forming gases in the form of easily extracted particulates. The committee's principal objective is to establish whether or not sorbent injection is viable for sulphur gas emission control in Alberta.

The first project funded by members of this group was carried out this year. The results are found in Sorbent Injection Study (see page 23).

[1]Committee members on March 31, 1989 were: Esso Resources Canada Limited, Edmonton Power, TransAlta Utilities Corporation, Alberta Power Limited, Luscar Ltd., Monenco Consultants Limited and the Alberta Office of Coal Research and Technology.

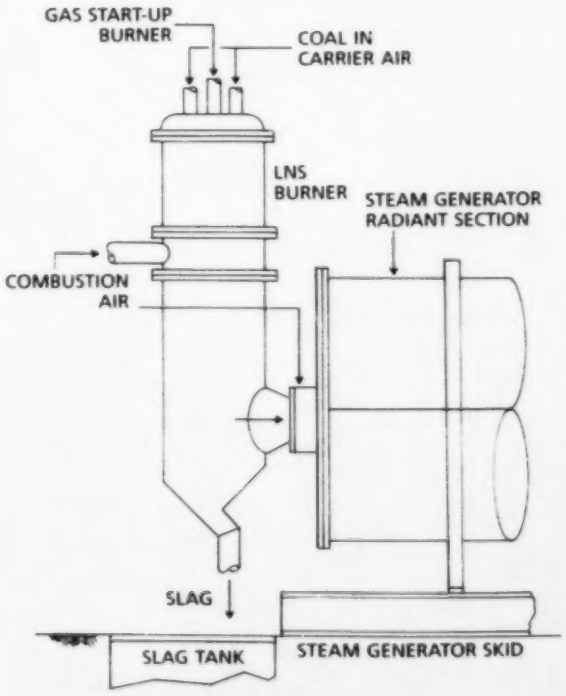
Application of the LNS Burner to an Oil Field Steam Generator

TRANSALTA RESOURCES INVESTMENT CORPORATION (CALGARY) AND OTHER PARTICIPANTS[2]

The Low NO_x/SO_x Burner (LNSB), is a multistage, slagging-type combustor intended to control SO_x and NO_x emissions simultaneously. The technology is owned by TransAlta Resources Investment Corporation. The LNSB uses advanced combustion concepts in a cost-effective manner to reduce SO_x emissions from coal combustion by between 70 and 90 per cent (as demonstrated with several coals, including those from the Whitewood mine) and suppresses NO_x emissions to less than 100 ppm. It also achieves 100 per cent burnout of carbon monoxide and 95 to 99 per cent overall carbon burnout. Preliminary studies indicate that the capital cost of equipping coal-fired boilers with LNSBs should be a fraction of the cost to obtain similar NO_x and SO_x control with state-of-the-art flue gas treatment systems. Also, operating costs should be greatly reduced. Incorporation of a slag separator allows oil- or gas-fired boilers to be converted to coal-firing.

[2]Other participants were: Esso Resources Canada Limited and Shell Canada Limited.

LNS Burner/Steam Generator Assembly



Pilot plant testing at 17.9 GJ/h has confirmed the design concept for the LNSB and verified that projected removal efficiencies can be achieved.

In 1986/87, the Office provided some financial assistance to complete the pilot plant tests and to prepare the detailed design of a 105.4 GJ/h commercial-scale demonstration unit.

Following establishment of the Coal-Fired Steam Generation for Heavy Oil Recovery Technical Committee last year, it was suggested that an intermediate-scale Low NO_x/SO_x Burner might be ideal for oil field applications, particularly because the burner can be retrofitted to current gas-fired steam generators. This represents an alternative to designing an all-new, coal-fired boiler. Therefore, a study was initiated this year to determine the feasibility of installing a LNSB on an existing 52.7 GJ/h steam generator. It would be required to burn low-ash, low-sulphur subbituminous coal, and must also be capable of being scaled up for use on current, commercial-scale heavy oil recovery plants rated at 189.7 GJ/h.

Consequently, demonstration-scale and commercial-scale designs were prepared to allow the LNSB to be used with horizontal, once-through steam generators. It is believed these designs can reduce emission levels to well below current Alberta and Canadian objectives for coal-fired steam generators.

Coal-Fired Steam Injection Boiler

FORDING COAL LIMITED (CALGARY)
AND OTHER PARTICIPANTS[1]

Fording Coal Limited, on behalf of the Coal-Fired Steam Generation for Heavy Oil Recovery Technical Committee, contracted Combustion Engineering Canada Inc. to proceed with a design and cost study for a 190 GJ/h pulverized, coal-fired boiler suitable for use in heavy oil recovery operations.

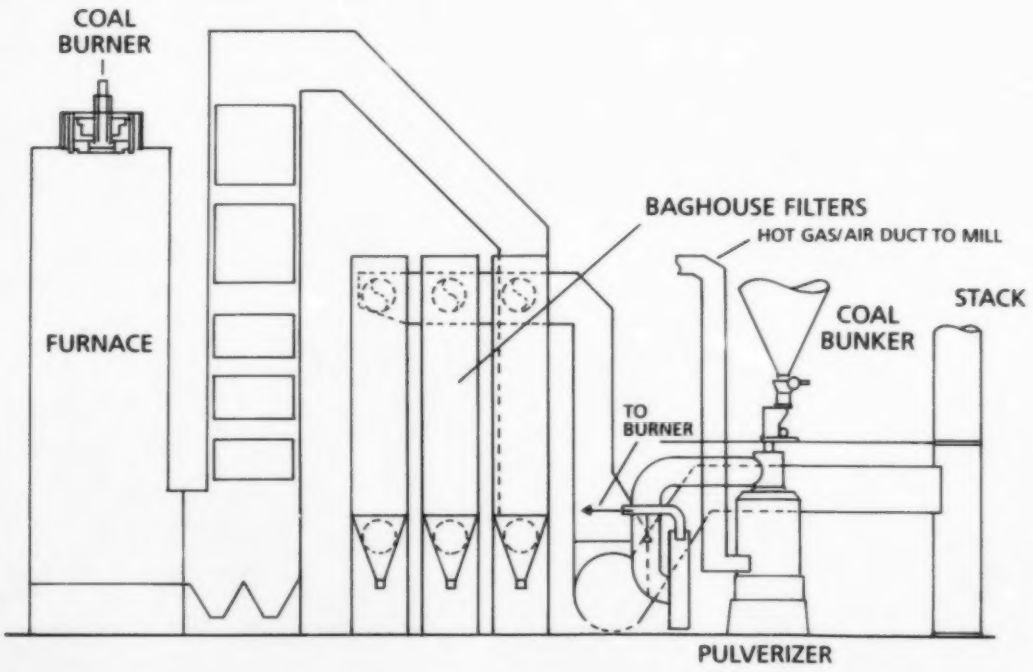
A vertical, down-fired, three-pass prototype steam generator was designed. It is capable of being fired with 10 different coals and is expected to satisfy all technical requirements for an oil field unit operating at Cold Lake, Alberta.

The design includes furnace sorbent injection technology capable of reducing the sulphur dioxide level of emissions to satisfy current federal guidelines for utility boilers. Also, the firing system and dust collection equipment were designed to satisfy existing guidelines for NO_x and particulates, respectively.

Specific design details are available only to project participants at this time.

[1]Other participants are: Luscar Ltd., Esso Resources Canada Limited, TransAlta Utilities Corporation, Shell Canada Limited and Alberta Power Limited.

Side Elevation of Proposed Coal-Fired Boiler



LNS Burner Steam Generator Demonstration

TRANSALTA RESOURCES INVESTMENT CORPORATION AND ESSO RESOURCES CANADA LIMITED, CALGARY

Based on the design and cost study described in the project, Application of the LNS Burner to an Oil Field Generator, a three-year project was initiated this year to demonstrate the LNSB at an Esso Resources Canada Limited heavy oil operation near Cold Lake.

The principal objectives of the project are to demonstrate:

- the ability to burn coal in an existing heavy oil recovery (HOR) steam generator using the LNSB. A stand-alone, 52.7 GJ/h steam generator will be built for this purpose;
- the capability of the LNSB to control SO_2 and NO_x emissions at satisfactory levels while firing Alberta subbituminous coals at a commercial scale under regular operating conditions; and
- the reliability and durability of auxiliary systems operating with the burner and steam generator.

Thus far, detailed engineering has been completed to allow the LNSB to be retrofitted to an HOR steam generator. Approval for the design has been received from the Energy Resources Conservation Board, and other permits have been received to allow construction to begin. The demonstration plant is scheduled to begin operation in early 1990.

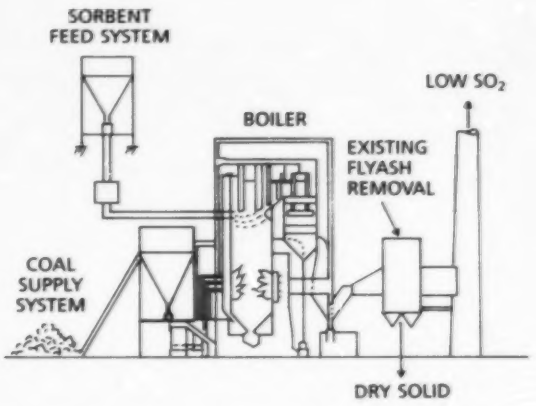
Sorbent Injection Study

ALBERTA POWER LIMITED (EDMONTON) AND OTHER PARTICIPANTS[1]

Although the plains coals of western Canada are generally low in sulphur, with contents ranging from 0.2 to 0.6 per cent by weight, coals from some reserves contain sufficient sulphur to exceed emission guidelines for sulphur dioxide when they are burned in conventional furnaces. Currently, these limits are 258 ng/J, but may be reduced in the future.

One cost-effective method for achieving modest levels of SO_2 control is to inject a finely ground sorbent into the furnace. For example, lime or limestone has been used for this purpose. Experience elsewhere in North America and Europe has shown that 50 per cent of the sulphur present in coal can be captured in this manner. The effectiveness of this technique with low-sulphur Alberta coals has not been demonstrated, however.

Sorbent Injection



Consequently, the state-of-the-art of sorbent injection was reviewed this year and assessments were made as to the likely capture of sulphur when Alberta coals are used.

From a limited amount of testing done in Saskatchewan, it was concluded that sulphur capture from coals having sulphur contents of approximately 0.5 per cent should range from 14 to 49 per cent. The Saskatchewan studies showed that use of hydrated lime produced better results than did limestone.

It was concluded that sorbent injection techniques have some potential for low-cost SO_2 reduction when used at existing power plants. It was recommended that bench-scale tests of Alberta coals and locally available sorbents should be undertaken to determine the best combinations for Alberta's coal-fired electricity-generating plants.

[1]Other participants were: Edmonton Power, Esso Resources Canada Limited, Luscar Ltd., TransAlta Utilities Corporation, Monenco Consultants Limited and CANMET.

Canadian Coal Gasification Technical Committee

In 1987, a consortium[1] of sponsors, headed by TransAlta Utilities Corporation of Calgary, funded an investigation of coal gasification technologies and applications. This included determining the potential of using Alberta coal in existing or emerging systems.

The study concluded that Integrated Gasification Combined Cycle (IGCC) systems now under development are demonstrating several advantages over current, coal-fired thermal technology for electricity generation. In particular, IGCC is considered the front runner of various proposed "clean coal" technologies intended to produce substantially fewer air emissions than conventional, thermal, electricity-generating systems. Although experience with large-scale IGCC systems is limited, all indications suggest they produce considerably lower NO_x and SO_x emissions than do conventional coal combustion facilities. Also, particulates are reduced significantly in comparison with conventional thermal plants. In addition, IGCC plants have higher thermal efficiencies than coal combustion plants, leading to lower carbon dioxide emissions.

Therefore, it was recommended that Alberta coal producers and researchers should become actively involved in IGCC developments. A technology transfer booklet, titled Gasification of Western Canadian Coals, was produced and distributed by the Alberta Office of Coal Research and Technology to encourage participation in a joint industry/government research program. Subsequently, the Canadian Coal Gasification Technical Committee[2] was formed to oversee and fund coal gasification projects comprising a multi-year research program. The objectives of this program are:

- to design and build a 100 MW (electrical) prototype IGCC plant in Canada by 1994;
- to establish and standardize coal gasification testing methods for Canadian laboratories; and
- to facilitate performance evaluations of Canadian coals in various coal gasification technologies.

The program has been divided into five major elements. They are:

- Technology assessment;
- Coal characterization;
- Exploratory experimentation;
- Engineering systems design; and
- Applications research.

Projects associated with these elements are to focus on each of the major steps involved in gasification, from preparing coal as feedstock to emission control.

Two projects funded in part by the Office and other members of the technical committee were completed last year. Also, some gasification research projects carried out at the Alberta Research Council and used to support technical committee projects were completed in 1987/88. Along with three Office-supported projects under way this year, approximately 10

[1]The consortium comprised: TransAlta Utilities Corporation (with Monenco Consultants Limited as the principal subcontractor), Alberta Power Limited, Luscar Ltd., Saskatchewan Power Corporation, Atlantic Coal Institute and the Alberta Office of Coal Research and Technology.

[2]As of March 1989, participants in the Canadian Coal Gasification Technical Committee were: TransAlta Utilities Corporation, Saskatchewan Power Corporation, Shawinigan Integ Inc., Shell Canada Limited, Westar Mining Ltd., Monenco Consultants Limited, Luscar Ltd., Alberta Power Limited, Unocal Canada Limited, Esso Resources Canada Limited, Gulf Canada Resources Limited, Nova Scotia Department of Mines and Energy, Saskatchewan Department of Energy and Mines, CANMET, and the Alberta Office of Coal Research and Technology assisted by the Alberta Research Council.

gasification studies have been undertaken thus far. Those under way are described in the Institutional Research section. Other members of the Canadian Coal Gasification Technical Committee sponsored additional projects. Included was a coal characterization study involving analysis and testing of coals from British Columbia, Alberta, Saskatchewan and Nova Scotia to enable predictions of coal behaviour under conditions encountered in various gasification reactors. Approximately 30 parameters were studied to establish basic composition and gasification characteristics of 20 coals. Testing was carried out by the Alberta Research Council and the Geological Survey of Canada, under the leadership of CANMET.

Also of interest to Alberta: this year CANMET was awarded a study on the co-production of hydrogen/carbon dioxide and electricity.

A second publication describing gasification projects supported by the Office was released. It is called Gasification of Alberta Coals and is available from Alberta Energy/Forestry, Lands and Wildlife information centres.

PYROSOL Process Development

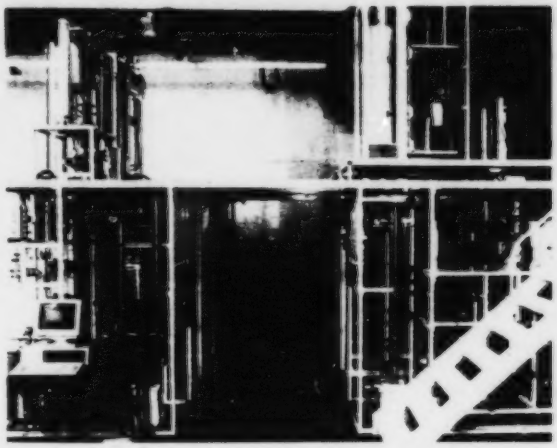
CANADIAN ENERGY DEVELOPMENTS INC., EDMONTON

Canadian Energy Developments Inc. is developing a process to make synthetic crude oil from subbituminous coal and bitumen. This process, known as co-processing, not only provides a method for producing synthetic crude oil from coal, but may also be useful in upgrading heavy oil.

The overall objective of the company is the design, construction and operation of a commercial-scale, co-processing upgrader in Alberta in the 1990s.

Currently, the company is simultaneously developing two co-processing schemes. One of these, known as PYROSOL, is a low-severity, two-stage process. It comprises mild hydrogenation and coking in a pressurized delayed coker under a hydrogen atmosphere.

The synthetic crude product from the PYROSOL process contains approximately 10 per cent naphtha, 60 per cent middle distillate and 30 per cent heavy distillate. It has the potential to be a premium product because it contains substantial quantities of middle distillate from which aviation and diesel fuels are made.



The PYROSOL and CCLC coal/heavy oil co-processing methods of Canadian Energy Developments Inc. are being tested and developed on this 227 kg per day process demonstration unit.

The second co-processing scheme, the CCLC process, involves coal solvolysis in a heavy oil slurrying medium followed by moderately severe hydrogenation of the solubilized coal and heavy oil.

The synthetic crude from the CCLC process is a light distillate containing approximately 35 per cent naphtha, 45 per cent middle distillate and 20 per cent heavy distillate. The product is substantially lighter than that produced by the oil sands plants in Fort McMurray.

Interest in these processes, and co-processing in general, stems from the fact that use of low-cost coal lowers the feedstock cost and the overall production costs of these upgrading schemes below those used to upgrade heavy oil or bitumen alone.

Since this process development project began in 1986, a 2 kg/h, two-stage hydrogenation bench-scale unit (BSU) and a 1.3 L pressurized delayed hydrocoker have been used to conduct operating severity studies. In these studies, hydrogenation pressure, temperature and reactor residence time were varied to control the distillable oil yield and maintain a high level of pitch conversion.

Also, a 227 kg per day continuous process demonstration unit (PDU) was commissioned by Canadian Energy Developments Inc. to allow long duration, continuous studies to be made on a larger scale. Throughout the year, numerous modifications were made to improve the system, and several successful commissioning runs were completed.

Studies aimed at optimizing the two processes and product quality continued this year. In the smaller reactors, distillable oil yields of up to 75 weight per cent of the total feed (daf-basis) were obtained for the CCLC process, and an average of 74.5 per cent for the PYROSOL process. The BSU was modified to allow two-stage testing and optimizing of the CCLC process.

Negotiations continued with Gesellschaft für Kohleverflüssigung mbH (GfK), to conduct testing in a 10 tonne-per-day pilot plant in the Federal Republic of Germany (FRG). GfK and the company are developing the PYROSOL process and a unique counter-flow reactor for the CCLC process.

A preliminary screening study was initiated to evaluate the technical and economic potential of a stand-alone coal/heavy oil upgrader using both PYROSOL and CCLC co-processing technologies. The study includes estimates of capital and operating costs for a plant projected to be built in 1993.

Coal/Heavy Oil Co-processing Management Committee

In mid-1988, it was decided that a technical committee[1] should be formed to assess the rationale and need for further development of technology suitable for co-processing of coal and heavy oil.

Formation of the committee was prompted by several developments in Alberta and other locations. For example, Ontario-Ohio Synthetic Fuels Corporation Ltd. is constructing a co-processing pilot plant in Ohio, and has suggested that a similar facility should be built in Alberta. Meanwhile, Canadian Energy Developments Inc. is continuing to develop its two co-processing schemes for Alberta, and CANMET is seeking industry partners to continue development of its co-processing technology. Also, the Alberta Research Council is continuing with its co-processing research program.

Furthermore, several feasibility studies have indicated that co-processing is a less expensive method than direct liquefaction for producing synthetic fuels from coal, and it might even be an alternative to the current method for upgrading heavy oil/bitumen to synthetic crude oils. Therefore, prospective participants in a joint industry/government investigation of the future of co-processing in Alberta held an initial meeting in August 1988.

The committee resulting from that meeting initiated a two-phase investigation to identify the relative merits and economics of coal/oil co-processing compared to heavy oil upgrading. The study will examine strategies affecting commercial development of co-processing technologies in Alberta.

[1]Current participants are: Canadian Occidental Petroleum Ltd., Alberta Power Limited, Gulf Canada Resources Limited, Husky Oil Operations Ltd., Shell Canada Limited, TransAlta Utilities Corporation, Saskatchewan Energy and Mines, Alberta Oil Sands Technology and Research Authority, and the Alberta Office of Coal Research and Technology.

Coal-Oil Slurry Pipelining

UNOCAL CANADA LIMITED, CALGARY

It has been estimated that the cost of transporting Alberta coal to Ontario can be reduced by at least 25 per cent if coal is slurried with oil and pumped through existing oil pipelines, rather than being shipped in bulk by rail as is done now.

Before the commercial potential of such a scheme can be determined, however, a detailed analysis must be made of alternative methods for introducing coal-oil slurries into pipelines. For instance, assuming the pipeline is also used to transport oil, the question of whether oil is contaminated by coal must be addressed. Furthermore, the feasibility of the concept depends on an ability to produce stable slurries economically and separate them into their respective coal and oil components at the other end of the pipeline.

This project was initiated last year and completed this year. The effect of particle-size distribution on coal-oil slurry characteristics was assessed in laboratory studies, and different techniques for separating coal-oil slurries were evaluated.

It was found that the viscosity of coal-oil slurries can be controlled and pipeline-stable slurries can be created. Using Obed Mountain coal, of which 60 to 70 per cent was finer than 200 mesh, coal-oil slurries were prepared which contained 50 per cent coal by weight. The viscosity of these slurries was found to be six to seven times greater than the oil from which the slurry had been prepared.

This year, laboratory testing revealed a procedure for preparing stable slurries capable of long-term storage or ocean transport up to 17 days without separating. Also, procedures were developed to separate 95+ per cent of the oil from the coal at the customer end of the pipeline. Analysis of the recovered coal and oil showed that feed and recovered coal are similar. The same is true for oils, except the asphaltene and sulphur contents of the recovered oil might be slightly less than in the feed oil.

A patent application has been prepared.

Coal Slurry Technology

SALZGITTER INDUSTRIEBAU GmbH,
FEDERAL REPUBLIC OF GERMANY

In this collaborative[1] project, an investigation is being made of the technical and economic feasibility of producing, transporting by pipeline and burning a coal-water slurry fuel made from Alberta coal using Salzgitter's DENSECOAL process. This is an alternative transportation scheme for lowering the delivered cost of coal in Ontario and other markets.

Last year, six Alberta coals were tested by Salzgitter to determine their suitability for producing fine-grained, highly-concentrated (70 weight per cent solids) coal-water fuels. It was found that slurry concentration was rank dependent. With medium-volatile coals, it was possible to produce stable suspensions having a solids concentration of 70 weight per cent, but the low-rank subbituminous coals produced unsuitable slurries containing less than 60 weight per cent solids.

Following these screening tests, a medium-volatile and a high-volatile bituminous coal were selected for larger-scale slurry production. Ten-tonne slurry samples were prepared by Salzgitter. One slurry comprised only the medium-volatile coal, while the other was a blend of the two coal types. Five tonnes of each slurry were delivered to the CANMET laboratories at Bells Corners (near Ottawa) for combustion tests, while pipeline and transportation stability tests were performed on the remainder by Salzgitter.

This year, combustion tests showed that neither slurry of Alberta coals could be recommended as an acceptable boiler fuel. This was because of unstable ignition properties. It was suggested that changes be made to improve the spray quality of the slurries, and a higher proportion of more volatile coal be incorporated into the coal blend.

At Salzgitter, the two slurries were transported through test pipelines ranging in diameter from 32 mm to 207 mm. It was concluded that both slurries exhibited stable behaviour and could be pumped long distances.

An alternative combustion-testing procedure was devised, with input from coal combustion experts from several research agencies. At year-end, arrangements were being completed to proceed with this work.

[1]Participants were: Ontario Hydro, Maritime Electric Company Limited, Trans Mountain Pipe Line Company Ltd., Interprovincial Pipe Line Limited, several coal producers, Bundesministerium für Forschung und Technologie (Federal Republic of Germany), and Energy, Mines and Resources Canada, in addition to the Alberta Office of Coal Research and Technology.

Institutional Program

The Institutional Research Program comprises a significant number of projects carried out by two non-profit research organizations: the Coal Mining Research Company and the Alberta Research Council.

Coal Mining Research Company

The Coal Mining Research Company is a private, non-profit company established in 1977 to provide industry and government with research, development and technology transfer services related to the mining and beneficiation of coal. Although the company was financed initially by A/CERRF (administered through the Office since 1984), an increasing proportion of its funding in recent years has been received from contract research work performed for mining companies, mining consultants and various government agencies.

Alberta Research Council

Since it was established in 1921, the Alberta Research Council has included energy resources research among its many scientific areas of interest. In recent years, this provincial Crown corporation has been actively involved in a broad range of coal-related investigations carried out by the Coal and Hydrocarbon Processing Department.

In recognition of ARC's expertise and the work this agency conducts for industry, it was decided that the aims of the Office and the Alberta Research Council could best be served if the latter undertook a range of projects in coal combustion, gasification and conversion.

In addition, the multi-year Alberta Coal Geology Project was initiated in 1986/87 by the ARC as a continuation of a coal exploration program begun in 1974. This project, which is jointly funded by the Office and the ARC, is primarily concerned with evaluating coal quality as it relates to uses for coal.

Automated Machine Control for Optimized Mining (AMCOM)

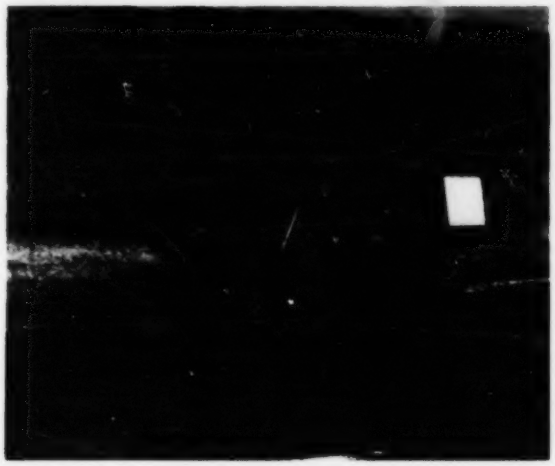
COAL MINING RESEARCH COMPANY, DEVON

Last year, a detailed review was made of non-cable vehicle guidance systems that might be used in Alberta's coal industry, and might also provide an opportunity to manufacture new products and diversify Alberta's economy.

Some of the reviewed technologies included systems based on inertial guidance, dead reckoning, radar, laser beacons, ultrasonics, machine vision and radio frequencies.

The most promising systems were investigated in terms of range, accuracy, flexibility, reliability and costs. Plans were developed for constructing a single prototype and testing it under local mining conditions.

Experience gained from this project led to the development this year of an improved dragline monitor (see Dragline Operations Monitor project, page 29), and an automated machine control system for selectively mining coal next to partings and waste material.



The AMCOM device, developed by the Coal Mining Research Company, was installed on a bulldozer and tested at a coal mine.

The latter device, known as Automated Machine Control for Optimized Mining (AMCOM), is intended to help reduce the amount of coal lost, and the amount of foreign material introduced, when mining occurs at coal/waste interfaces. In some mining operations, for example, more than 10 per cent of total coal reserves are lost in this manner. In other cases, excessive amounts of foreign material are mixed with coal. This causes problems in power plant boilers and preparation plants.

The AMCOM design comprises four modules, each of which uses proven, off-the-shelf components. The four modules are:

- a coal quality sensing module;
- a computing/lithology-mapping module;
- a navigation/vehicle-position tracking module; and
- a machine control module.

This year, all four modules were developed and installed on a Bobcat loader for initial field testing. The test showed that the AMCOM could control the elevation of the Bobcat bucket within 10 mm of the required position. Subsequently, the system was installed on a bulldozer and tested at a coal mine. Here, the system provided a reliable electronic map of the elevation of the coal/waste contact in the working area, and the control strategy employed by AMCOM provided the required control precision.

Publication

Daugela, G.C., B.G. Hollingshead, G.L. Hoffman and R.A. Wilson. 1989. Automated Machine Control for Optimized Mining. CMRC Report CF8819-1.

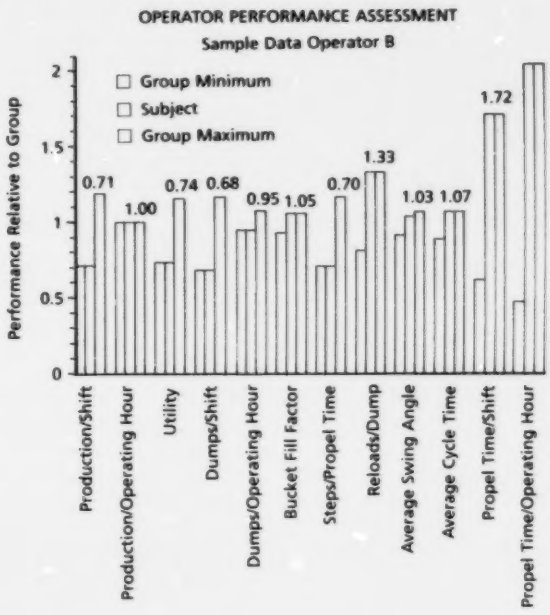
Dragline Operations Monitor

COAL MINING RESEARCH COMPANY, DEVON

The second project evolving from the non-cable vehicle guidance project, which was completed last year, concerns development of a dragline monitor to help improve the efficiency of dragline operation and reduce mining costs.

In a typical overburden-removal operation at an open-pit coal mine, a dragline operator is required to co-ordinate several controls and make frequent changes to operating techniques. Without some form of measuring device, it is difficult for a dragline operator to determine accurately the advantages of one technique over another. A dragline monitor, however, can record information quantifying the performance

Dragline Operations Monitor Sample Report



of the dragline in various operational modes and the performance of the operators as they use different techniques.

In this project, an existing dragline monitor was obtained from the U.S. and modified to record various machine functions. The modifications were made primarily to assure the generation of confidential information, but other alterations were made to accommodate the requirements of western Canadian coal mine operators.

Actual data from a U.S. coal mine were used to demonstrate the monitor's capabilities. It was concluded that the device could be used successfully to train operators and it might enhance the prospects of partially automating the operation of a dragline.

Publication

Daugela, G.C. and B.G. Hollingshead. 1989. Dragline Operations Monitor, Final Project Report. CMRC Report CF8818-1.

Washery Optimization

COAL MINING RESEARCH COMPANY, DEVON

Largely because of their geologic setting, Alberta's mountain and foothills coals have been exposed to forces that cause them to be friable. This means that sizeable amounts of fines are present in these coals. Also, they are more difficult and expensive to clean and recover than coarser coals. However, fines are present in sufficient quantities (up to 40 per cent of the product stream) to justify continual research efforts aimed at minimizing their loss and improving minesite costs.

In this multi-year project, efforts continued this year to test the performance of fine coal separators. Pilot-scale evaluations were made of a spiral separator unit and a two-stage, water-only, cyclone circuit. The objective was to measure changes in their performance under conditions of fluctuating feed. Samples of raw feed (0.6 x 0.15 mm) were prepared with 20, 30 and 40 per cent ash content. The separators were operated in a closed-circuit (steady-state) mode to obtain the best operating conditions for cleaning the three coal feeds. Then the separators were operated in an open-circuit configuration. This allowed each separator to receive feed at fluctuating ash contents. The frequency of the controlled feed fluctuations was changed over a 16:1 time ratio in a series of five tests for each separator.

From analysis of the clean coal and rejects, and the use of various methods of measuring the degree of separation under steady-state and fluctuating feed conditions, it was concluded that under steady-state conditions the efficiency of each separator was as anticipated from previous literature accounts. However, when either separator was operated under fluctuating feed conditions, the yield losses were at least one-third higher than those obtained in the steady-state tests. Hence, plant designs should include some means of providing a steady feed to fine coal processes. Open-circuit tests were recommended when the results are to be used to predict yields.

Publications

McIntosh, P.S. and M.J. Kramer. 1986. Washery Optimization: Literature Review of Performance Tests. CMRC Report 8659-1.

Germain, R.J. and P.S. McIntosh. 1987. Washery Optimization: Evaluation of Ash Downgrade Ratio Curves. CMRC Report 8659-2.

Adamson, D.G., P.S. McIntosh and S.G. Butcher. 1988. Washery Optimization: Performance Fluctuations in Fine Coal Separators. CMRC Report 8759.

WESTCOAL Separator

COAL MINING RESEARCH COMPANY, DEVON

During the past decade, spiral separators have been introduced to improve recovery of coal fines during cleaning. However, experience with these devices has shown that they cannot clean western Canadian coal to the degree necessary to optimize production and satisfy out-of-province and export markets. Therefore, the objective of this project is to design and develop a device, known as the WESTCOAL Separator, for coals with more difficult cleaning characteristics.

A basic form for the separator was established. It is configured to give a low-density cut point. A field demonstration reduced the clean coal ash content by two per cent.

Coal Production Program Planning

COAL MINING RESEARCH COMPANY, DEVON

The services of Coal Mining Research Company personnel were provided on an as-required basis to assist the Office in preparing research and technology development plans related to improved coal production and processing.

Subjects investigated this year included the following: a catalogue of persons and firms having expertise in geomechanics and mining engineering research; the potential for application of geostatistics to coal production; the commercial potential for extraction of heavy metals and rare earth metals from coal ash; and assessment procedures for coal production technologies.

Alberta Coal Geology Project

ALBERTA RESEARCH COUNCIL, EDMONTON

The Alberta Coal Geology Project is jointly funded by the Alberta Office of Coal Research and Technology and the Alberta Research Council. Its overall objective is to improve the Alberta coal information base in areas where it is deficient so that industry and government can focus better on future coal development plans.

From 1974 to 1986, a coal exploration program carried out by the Alberta Research Council made a general assessment of coal reserves in Alberta's plains region, including the development of methods to predict the distribution, thickness and continuity of coal seams. The current three-year project was begun in 1986/87, and placed greater emphasis on coal quality in the plains, foothills and mountain regions. The project comprises four subprojects as follows:

Quality of Plains Coal

In response to the need by coal companies and planners to predict confidently the properties of coal at varying distances from known data points, this project is developing geostatistical and geological models for the plains region. Specifically, an understanding is being developed of the factors controlling coal quality in the Drumheller (Horseshoe Canyon Formation) and Ardley (Paskapoo Formation) coal zones.

Last year, six coal seams at the Highvale mine site were examined to quantify the degree of variability in coal quality factors.

This year, a regional mapping investigation for near-surface coals in the Ardley coal zone was completed. Coal quality maps were produced for ash and sulphur. The maps display an uneven distribution of data locations (caused by a concentration of drillholes in active mining areas) and a large range of values (perhaps caused by variations in sampling technique). This shows that sampling bias must be considered in future coal quality programs. The investigation indicates that the Highvale and Genesee mine sites have the lowest ash and sulphur coals within the Ardley coal zone.

The frequency distributions of ash and sulphur were analysed using probability density functions.

A Regional Evaluation of Coal Quality in the Foothills and Mountains

In earlier coal geology investigations, a broad synthesis of coal quality data for the plains region was made, but no such synthesis has been made of existing data from the foothills and mountains. Therefore, this project aims to develop a better geologic understanding of coal quality in those regions.

Last year, a regional statistical and geological analysis of all publicly available coal quality data for the foothills/mountains regions in southern Alberta was completed. A similar study for the northern portion of the coal-bearing area of the province was completed this year. The data supplied by the Energy Resources Conservation Board for the northern study were found to contain several thousand coal quality analyses for the three primary coal zones in the area, namely Luscar, Obed Marsh and Coalspur. While this provided a reliable data set for statistical analysis, most of the data points were concentrated in and around the four operating mines. Therefore, additional sampling was undertaken, but significant gaps in knowledge still exist.

New microcomputer-based statistical software proved to be cost-efficient and reliable. Coals of the Luscar Group are showing both north-south and east-west systematic variations in coal rank.

Foothills and Mountains Coal Quality - Local Study

In this project, a detailed study is being made of coal quality variations in the structurally deformed coal-bearing sequence. This is being done to establish baselines for procedures to assess coal quality, to compare coal quality data from different areas of the foothills and mountain regions, and to determine the effects of folding and faulting on coal quality.

Detailed sedimentological studies were done for strata immediately overlying and underlying the major economic seam of the Cadomin-Luscar coal field. Some variation in ash and sulphur can be explained by the sedimentary environment. Ash contents have been locally increased by tectonic shearing. Analyses of the various quality parameters show that only sulphur and nitrogen are distributed normally. A final report was written this year.

Data Base Management and Natural Resources Information System

In support of the other projects in the program, a data base is being designed and maintained in a form useful to planners and resource managers. Integration of data from the Energy Resources Conservation Board, coal companies and the Alberta Research Council began last year, using the INGRES data management system. Also, development of a Geographic Information System (GIS) pilot project was begun last year by mapping an area west of Edmonton that included the Genesee, Highvale and Whitewood mines. Results from this study were demonstrated this year, and should serve to help model other systems containing data for the entire province.

Publications

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Langenberg, C.W., W.D. Kalkreuth and C.B. Wrightson. 1987. Deformed Lower Cretaceous Coal-Bearing Strata of the Grande Cache Area, Alberta. Alberta Research Council Bulletin No. 56.

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Mandryk, G.B. and R.J.H. Richardson. 1988. Coal Resource Data in the Plains Area of Alberta. Alberta Research Council Open File Report 1988-07.

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Wong, R., R.S. Strobl, R. Krzanowski and N. Chidambaram. 1988. Exploratory Statistical Analysis of Coal Quality at the Highvale Mine, (Ardley Coal Zone), Central Alberta. Alberta Research Council.

Coal Characterization and Utilization

During 1985/86, Alberta Research Council scientists began to study the combustion characteristics of Alberta coals, and the following year they added coal gasification studies to their research activities. When combined with expertise acquired since 1979 in coal liquefaction and co-processing, ARC's coal characterization capabilities have become a valuable asset to the province. Development of these skills has been encouraged by the Office in a series of ongoing research projects. In the past, these projects were funded individually, but this year a new funding agreement was reached with the Alberta Research Council. It provides a broader framework to allow ARC staff to increase their understanding of the relationships between coal properties and coal behaviour in various utilization technologies such as combustion, gasification and co-processing.

Projects funded under this umbrella program are described in the following section.

Combustion Properties of Alberta Coals and Chars

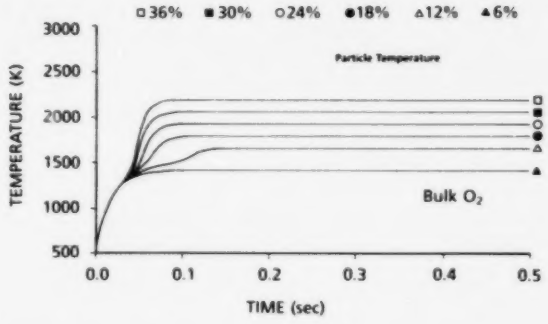
ALBERTA RESEARCH COUNCIL, DEVON

It is well-known that some coals burn faster and more completely in a variety of combustors, but the reasons for this behaviour remain unclear. To obtain a better understanding of coal combustion phenomena, this project was initiated with the objective of creating a conceptual and numerical model of single-particle combustion.

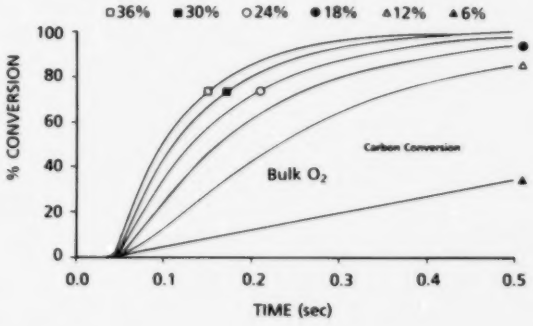
Coal and char combustion were studied in a flat-flame burner that simulated gas compositions and particle heating rates typical of combustion processes. Also, studies were made in a larger, laminar-flow combustor having a feed rate of 3 kg/h. While smaller combustors were used for fundamental studies, the laminar-flow unit was upgraded and used to simulate the time/temperature history of coal combustion in a typical commercial-scale boiler. A swirl burner was installed to achieve higher temperatures, which are more typical of actual coal flames.

A mathematical model was developed to analyze the reaction of a single char particle in combustion or gasification atmospheres. This model examines the heat and mass transfer, and chemical reactions occurring in the boundary layer around a reacting char particle. This analysis showed that combustion of carbon monoxide to carbon dioxide in the boundary layer significantly affects particle temperature. When calculating char reaction kinetics from experimental data, this effect should be considered.

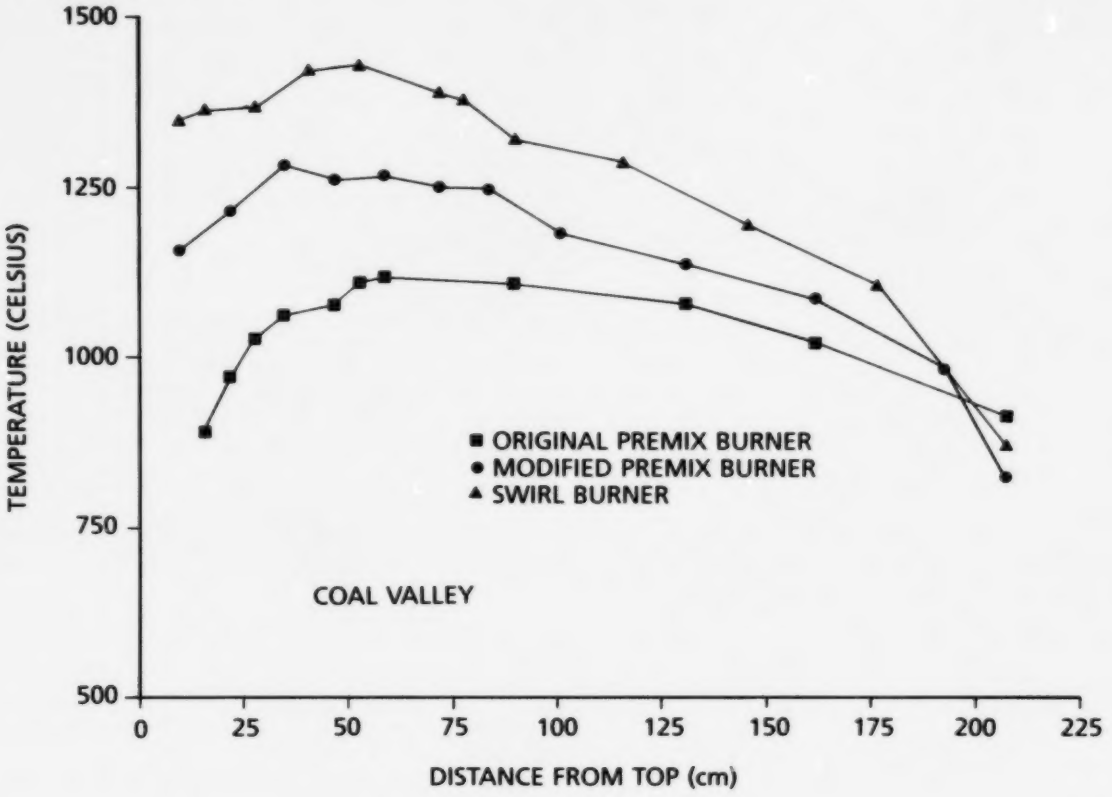
Particle Temperature



Carbon Conversion



Effect of Burner Design on Wall Temperature Profiles in the 3 kg/h Combustor



Gasification Behaviour of Alberta Coals

ALBERTA RESEARCH COUNCIL, DEVON

Last year, five coals supplied by five Alberta coal producers were evaluated for their suitability and performance in Texaco, British Gas and Shell gasifier technologies. All are candidates for commercial-scale Integrated Gasification Combined Cycle plants. While both the Texaco and Shell processes are examples of entrained-flow systems, the British Gas process is representative of a fixed-bed gasifier.

Within the scope of the project, each company evaluated the coals, but actual gasification experiments were not performed. Therefore, these evaluations were regarded as initial screening tests only. For coals judged to be suitable, the gasifier companies supplied information on predicted mass and energy balances and a gasifier product gas composition.

The economics of any coal gasification process are influenced greatly by the composition of the product gas. Therefore, Alberta Research Council investigators gained some experience in predicting product gas composition by working with a mathematical model designed for this purpose. The model was used to make calculations based on published data for coals from several sources that had been gasified in the Texaco, PRENFLO and KRW gasifiers.

Also, calculations of product gas composition and other data from the Cool Water gasification plant in California were used to obtain some experience with computerized simulations of IGCC plants.

Publications

Kovacik, G., B. Ozum and A.K. Chambers. 1988. Gasification Characterization of Alberta Coals. Alberta Research Council.

Kovacik G. and A.K. Chambers. 1988. Evaluation of Canadian Coals for Gasification with Texaco, British Gas and Shell Technologies. Alberta Research Council.

Devolatilization Properties of Alberta Coals

ALBERTA RESEARCH COUNCIL, DEVON

Over the past 20 years, coal combustion research has indicated that the behaviour of volatile matter during the first few milliseconds of exposure to high temperatures may determine the combustion characteristics of a particular coal. Although studies have been made of this "devolatilization" behaviour under low rates of heating, little is known about it under the high heating rates experienced in entrained-flow combustion and gasification processes.

In this project, three coals were heated at 800°C for various periods of time, and a high-temperature furnace was obtained for experiments up to 1 600°C. An alternative apparatus comprising a flat flame burner was used for high-temperature devolatilization studies under rapid heating conditions. It was found that devolatilization must be studied under slightly oxidizing conditions to prevent recondensation of coal tars onto the char.

Further experiments are planned for next year. The data will be used in a numerical model of the devolatilization process.

This project is closely related to the Combustion Properties of Coal and Chars project. It is expected that findings from both projects will complement each other and establish laboratory-scale techniques for characterizing Alberta coals and coal products.

Publication

Malychuk, M., A.K. Chambers and D. Ungarian. 1989. Devolatilization Properties of Alberta Coals. Alberta Research Council.

Flat flame burner used at Alberta Research Council.

Gasification Properties of Alberta Coals, II

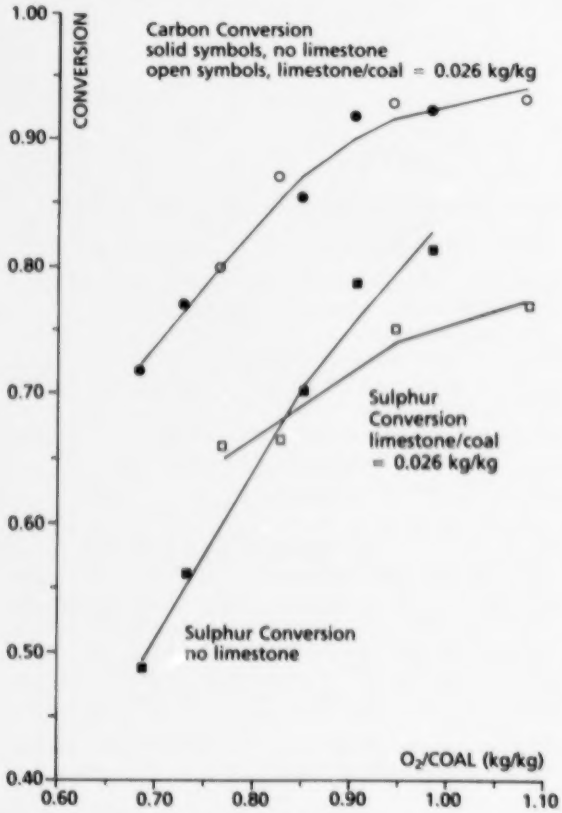
ALBERTA RESEARCH COUNCIL, DEVON

This year, the Alberta Research Council negotiated access to a state-of-the-art entrained-flow gasification research and development facility at Brigham Young University in Utah. Consequently, one ARC staff member was placed at the facility to study gasification of Alberta coals at high heating rates. This work is concurrent with development of a gasification testing protocol for the Canadian Coal Gasification Technical Committee.

Highvale coal was gasified in Brigham Young's entrained-flow gasifier. A range of oxygen-to-coal ratios was investigated. Carbon conversions of up to 95 per cent were observed, and the product gas heating value was in the range of 6.2 to 9.0 MJ/m^3.

A gasification testing protocol was developed in co-operation with CANMET. Relevant tests were completed for seven Alberta coals and 14 other

Elemental Conversion (solids basis) vs O_2/Coal Firing of Highvale Coal in the Brigham Young University Entrained Bed Gasifier



coals from across Canada. The results of these evaluations were compiled to produce a data bank that will serve as a reference for all Canadian coals thought to be suitable for gasification processes. Also, the data bank can be used in simulations that determine the suitability of a particular coal in a specific gasification process.

Publications

Kovacik, G., M. Oguztoreli, A.K. Chambers and B. Ozum. 1989. Equilibrium Calculations in Coal Gasification. Alberta Research Council. (Submitted to International Journal of Hydrogen).

Kovacik, G., A.K. Chambers and B. Ozum. 1989. Gasification Characterization of Alberta Coals. Alberta Research Council.

Kovacik, G. A.K. Chambers and B. Ozum. 1988. Staff Training: Gasification Process Research. Alberta Research Council.

Kovacik. G., A.K. Chambers and B. Ozum. 1988. Study of Fundamental Gasification Properties of Alberta Coals. Alberta Research Council.

Kovacik, G., A.K. Chambers and B. Ozum. 1988. Gasification Characterization of Alberta Coals. Alberta Research Council.

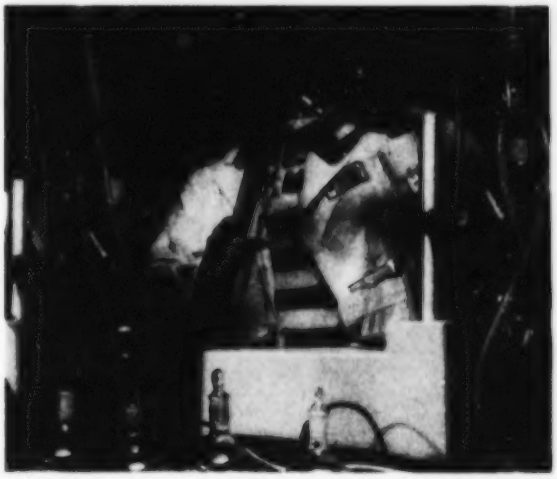
Kovacik, G., A.K. Chambers and B. Ozum. 1988. Laboratory-Scale Facilities to Study Gasification Properties of Alberta Coals. Alberta Research Council.

Chemistry of Coal Liquefaction

ALBERTA RESEARCH COUNCIL, DEVON

The chemical changes that occur when coal is liquefied or bitumen is upgraded are complex and difficult to follow from an analytical perspective. However, when the two processes occur simultaneously, as they do in co-processing, it is even more difficult to understand the chain of events that ultimately leads to products.

Consequently, a project was initiated in 1985 at the Alberta Research Council to gain a better understanding of the transformation processes that occur during coal/bitumen co-processing. The work entailed developing chemical and physical characterization methods for co-processing feedstock and reaction products, and developing a method to characterize product performance. This involved an "analysis tree" comprising the following: separation of high- and low-molecular weight components; separation of resins from oils; separation of hydrocarbons into saturates and several aromatic fractions; separation of asphaltenes by size; the use of field-ionization mass spectrometry and thermogravimetric analysis; evaluation of structural groupings in asphaltenes by nuclear magnetic resonance (NMR); and determination of the octane and cetane indices of the reaction products. These latter indices are



Laboratory facilities, such as these, were used to characterize the products of co-processing.

important in evaluating synthetic crude oils as potential oil refinery feedstocks.

Normally, large samples are required for cetane-number engine tests; however, an NMR method was used to develop a cetane index procedure for small samples as a substitute for diesel engine tests. The method was calibrated with normal refinery feedstocks and applied to light and middle distillates from three coal/bitumen co-processing experiments. Correlations were established between the NMR data and the engine test.

Also, a standardized procedure (known as PNA analysis) for analysing paraffins, naphthenes and aromatics was used routinely. These methods were used successfully to analyse reaction products from a variety of liquefaction processes, including the coal/bitumen co-processing scheme of Canadian Energy Developments Inc. Special attention was paid to the asphaltene fraction because asphaltenes are known to play an important role in co-processing reactions. Studies showed that the identity of the asphaltene source and its degree of degradation to simpler molecules could be determined by these analytical methods.

The analytical procedures necessary to evaluate a refinery feedstock and perform detailed chemical characterization of coal/bitumen co-processing products were developed successfully in this project. It is believed that routine use of these techniques could lead to a definition of lower-severity co-processing conditions.

Publication

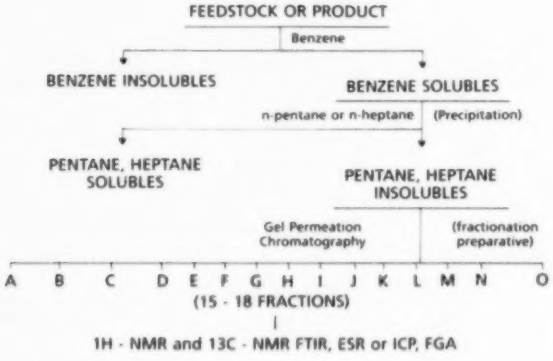
Selucky, M.L. 1988. Product and Process Characterization: Analytical Evaluation of Coal/Bitumen Coprocessing Products. Alberta Research Council.

Product and Process Characterization

ALBERTA RESEARCH COUNCIL, DEVON

This project, initiated this year, is a continuation of the work begun in the Chemistry of Coal Liquefaction project. Whereas the initial work concentrated on analytical methods that might be used to characterize co-processing products and help define those that are desirable, this project aims to develop an understanding of the chemical changes that occur when coal and bitumen react. This should help researchers to understand the effects of process changes on the products. It involves additional characterization of co-processing products to determine better the reaction pathway occurring when coal and bitumen are co-processed to produce synthetic crudes. Also, high-molecular weight components of the product stream will be characterized to help understand their contribution to coking phenomena. New analytical techniques will be tried as well.

Analysis Schematic for Feedstock and Product Asphaltenes


FEEDSTOCK OR PRODUCT
Benzene
BENZENE INSOLUBLES
BENZENE SOLUBLES
n-pentane or n-heptane
(Precipitation)
PENTANE, HEPTANE SOLUBLES
PENTANE, HEPTANE INSOLUBLES
Gel Permeation Chromatography
(fractionation preparative)
A B C D E F G H I J K L M N O
(15 - 18 FRACTIONS)
1H - NMR and 13C - NMR FTIR, ESR or ICP, FGA

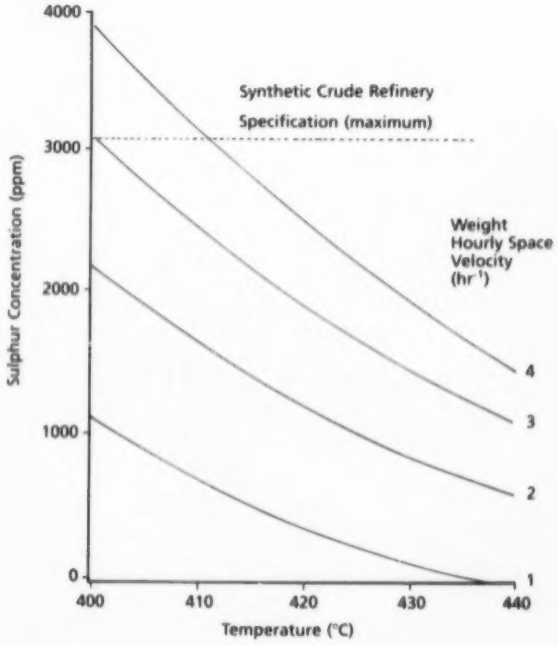
Secondary Upgrading of Co-processing Products

ALBERTA RESEARCH COUNCIL, DEVON

Last year, a project was undertaken to begin studies of secondary upgrading of coal/bitumen co-processing products. The primary objective was to examine the options for removal of sulphur and nitrogen heteroatoms in the 200-300°C and 301-524°C fractions of products obtained from coal/bitumen co-processing. This is necessary to satisfy current refinery feedstock specifications. A secondary objective of the project was to quantify the amount of coal-derived carbon incorporated into the products of primary and secondary upgrading.

The products from the first stage of co-processed Highvale subbituminous coal and Athabasca bitumen were hydro-treated using a continuous tubular reactor and Ni-Mo/Al_2O_3 catalyst. Upon analysis, it was found that sufficient nitrogen was removed from the products, but the sulphur content of the naphtha fraction still exceeded refinery specifications. The hydro-treating process was then used to upgrade certain fractions of product from the co-processing scheme of Canadian Energy Developments Inc. (CED).

Variation of Sulphur Concentration with Secondary Upgrading Conditions



Using the stable isotope mass balance method, the upgraded products of Highvale coal/Athabasca bitumen co-processing were successfully analysed for coal-derived carbon.

While these experiments showed that some co-processing products could be upgraded to satisfy specifications for refinery feedstocks, a second project was initiated this year to identify optimum conditions for heteroatom removal and examine process options for producing marketable transportation fuels.

Thus far, a range of upgrading conditions for one sample of CED product was established to allow sulphur and nitrogen specifications to be met. At year-end, a sufficient quantity of CED sample had been hydro-treated to enable a cetane number engine test to be performed on the middle distillate fraction. In this preliminary study, the upgraded middle distillate met or exceeded several of the Canadian Standards specifications for diesel fuel.

Publication

Ohuchi, T., M. Carmichael and A.K. Chambers. 1989. Secondary Upgrading of Co-processing Products and Production of Transportation Fuels. Alberta Research Council.

Coal Utilization Program Planning

ALBERTA RESEARCH COUNCIL, DEVON

The services of a combustion engineer from the Alberta Research Council were provided to the Office to oversee research activities under the International Energy Agency (IEA) Annex II projects (see Strategic Research Section, page 18), and to represent the Office during meetings of the Canadian technical committee and the IEA executive committee for this Annex.

This year, two technical committee meetings and one executive committee meeting were attended. Seven reports describing IEA research projects were reviewed, and assistance was provided in formulating an extension to the IEA Annex II research program. The presence of an Alberta representative is important to ensure the research program addresses Alberta's interests.

Two Alberta Research Council staff participated in site visits to industrial and university coal research centres in Japan. This travel was hosted by the Japanese government as part of the Japan-Canada Joint Academic Research Program - Developing Advanced Processes for Efficient Uses of Coal.

Publication

Chambers, A.K. 1989. Coal Utilization Program Planning. Alberta Research Council.

Coal Research Grants Program

One of the aims of the Office is to encourage scientific excellence in coal-related fundamental research.

To help reach this goal, the Coal Research Grants Program was established to provide funding to university researchers. The Coal Research Technical Panel was formed to evaluate research grant applications and recommend projects for funding. The panel[1] comprises representatives from the three Alberta universities, industry, the Alberta Research Council, the Coal Mining Research Company, The Coal Association of Canada and the Office.

The first competition under this program was held in January 1985. Since then, 25 projects have been initiated, of which nine were completed during 1988/89.

[1]Coal Research Technical Panel members in 1988/89 were: K.E. Cooper (Chairman), D. Spratt, A. Hardin, E. Haniuk, N. Berkowitz, R.T. Marshall, R. Chopiuk, H. Sahay and E.J. Barry.

Time-Dependent Behaviour of Coal Measure Rocks

UNIVERSITY OF CALGARY (R. DAY), CALGARY

In planning underground coal mines in western Canada, it is important to be aware of the likely behaviour of soft rocks that commonly surround coal seams. For example, the roofs of mine shafts can sag, floors can heave and pillars can deform appreciably. Many of these changes are not predicted accurately by current methods.

In this project, initiated in 1986, computer simulations were developed to predict the creep behaviour of rocks, coal and potash using data from simple, rapid testing of cores.

Earlier in the project, a coal mine simulation model was developed that could be run on a microcomputer. This was followed by collection of data on creep properties through literature studies. Then, creep behaviour was predicted by the model and compared with actual test data. Various refinements were made to the model to obtain better correlations between predictions and laboratory data.

Incremental load tests to substantiate key aspects of the creep model were completed. Tests were performed on some potash samples, which have creep characteristics similar to those of coal.

Seismic Modelling of Shallow Coalfields

UNIVERSITY OF CALGARY (D.C. LAWTON), CALGARY

In recent years, experimentation with a technique known as surface reflection seismography has indicated that it could be used to search for and evaluate coal in situ, but its use has been limited to determining whether coal is present. This project attempted to demonstrate that quantitative interpretation of coal reflection seismic data is possible. By first comparing synthetic seismograms with information from acoustic and density drillhole logs obtained from coal deposits, followed by two- and three-dimensional seismic modelling, it was anticipated that the thickness, geometry and number of coal seams in a deposit could be interpreted from seismic data.

Interpretation of field seismic logs, in conjunction with the results of numerical and physical modelling experiments, revealed that density contrasts between coal and host sediments were primarily responsible for the reflectivity characteristics of plains coal. Furthermore, studies of synthetic seismograms showed that small variations in seam thickness and separation significantly affected the overall seismic response. Signal resolution, however, was dramatically affected by the placement of acquisition equipment in the field. It was shown that near shot-receiver offsets are preferred in seismic exploration for shallow coals. It was observed that reflection seismic surveys can be useful in mapping coal pinchouts and wash-out zones ahead of mining operations.

This year, high-resolution reflection seismic data were collected at the site of a coal-mine near Camrose. This site was chosen because it allowed field testing of approaches learned from the modelling work, and comparisons could be made with results from earlier investigations at this site. Very promising results were obtained, and bed thicknesses in the range of 3 m could be resolved. Additional data interpretation was under way at year-end.

Also this year, a physical model of a delta-plain coal deposit was constructed at the University of Calgary. It was made from Plexiglas, polyvinylchloride, polyethylene sheeting and cement. A simulated coal zone and other geological features were incorporated to determine whether surface reflection seismic measurements made over the model would delineate the features of interest.

Deformation and Progressive Failure of Open-Pit Highwalls

UNIVERSITY OF ALBERTA (N.R. MORGENSTERN), EDMONTON

When a highwall fails in an open-pit mine, the falling debris can injure workers, damage mining equipment and cause costly delays. Some of these difficulties can be avoided or minimized if improved methods of predicting highwall failure can be developed.

In this project, begun in 1986, highwall deformation was studied as mining progressed in an open pit at the Highvale mine. In plains mines in particular, the soft bedrock is broken into small blocks by fractures and joint systems. Excavations in this material cause significant deformations that stretch the bedrock. This opens the fissures and spreads the rock blocks farther apart. The result is a loosened rock mass that is weakest near the face of the highwall. The relationship between loosening caused by excavation and subsequent strength reduction is called the "loosening mechanism." It was the focus of this project.

Horizontal and vertical surface deformation was measured using survey techniques that employ a series of tiltmeters installed in rows parallel to the highwall face. Piezometers were used to measure variations in the water table, and the strata comprising the highwall were analysed for stress-strain properties.

During the monitoring phase of the project, significant movement was detected in several shear zones. The instrumentation was able to detect the onset of highwall movement, the extent of movement behind the highwall crest and variations in the deformation mechanisms over a short distance.

The degree of loosening was expressed as a "loosening strain," which was obtained by differentiating the horizontal deformations caused by excavation. For example, where the loosening strain approached zero behind the highwall face, the bedrock was considered to be unloosened. However, the loosening strain reached a maximum in the fully loosened state at the highwall face.

The undisturbed rock strength was approximated from laboratory testing, taking into account the effect of discontinuities. The fully loosened strength, however, could only be calculated from analyses of highwalls that had failed.

The discovery of a connection between extension strain and strength reduction provides a basis for the development of more effective analytical and monitoring strategies.

Particle Distribution in Slurry Flow Through Tees and Manifolds

UNIVERSITY OF ALBERTA (J.H. MASLIYAH), EDMONTON

Two-phase (solid/liquid) flow through a manifold is used commonly in industry to distribute solids to various processing units. This occurs in coal preparation plants as well. Because of differences in inertia between the solid and liquid phases, the solids concentration is not always the same in various branches of the manifold. The objective of this project is to determine the operating conditions that will allow equal solids distribution in the branches.

A closed-loop piping arrangement having a manifold with four branches and valves to control slurry flow through the branches was constructed this year. Isokinetic and conductivity probes were installed to measure solids concentration upstream and downstream of the branch tees. Also, the effects of branch size and spacing will be studied. Initial experiments involving sand/water slurries were begun, but coal/water slurries will be used in later experiments.

A Thermodynamic Model for the Spontaneous Combustion of Coal

UNIVERSITY OF CALGARY (R. PAUL), CALGARY

In recent years, some progress has been made in understanding the causes of spontaneous combustion and in characterizing coals according to their susceptibility to this phenomenon. However, all the conditions existing in a coal storage facility cannot be reproduced in a laboratory. Therefore, the objective of this project is to develop a reliable, thermodynamic model of spontaneous combustion that might be used to predict the likelihood of a self-heating event. If this were possible, the model could serve as the basis of a monitoring and warning system and could be used to optimize coal transport and storage conditions to reduce the risk of spontaneous combustion.

A model consisting of four differential equations is being developed to describe the following aspects of self-heating: exothermic oxidation; oxygen transport; heat of wetting; heat of evaporation; moisture transport; and decomposition of peroxides above 70°C.

Thus far, the critical values and the relative importance of factors governing spontaneous combustion were identified using a one-dimensional model. An empirical formula was developed for the heat of wetting for various Alberta coals. It corresponded well with experimentally determined numbers.

Isotopic Studies of Coal/Bitumen Co-processing Schemes

UNIVERSITY OF ALBERTA (K. MUEHLENBACHS), EDMONTON

In an earlier project supported by the Office, an analytical technique, known as isotope mass balance, was successfully used to measure the ratio of carbon 13 to carbon 12 isotopes in coal and bitumen. It allowed researchers to differentiate between the carbon derived from coal and the carbon derived from bitumen in the products of coal/bitumen co-processing.

In 1987/88, a new project was begun as a co-operative effort involving researchers at the University of Alberta and the Alberta Research Council. In it, the isotope mass balance technique is used to determine optimum coal/bitumen reaction conditions. Also, the technique is being used to evaluate the results of secondary upgrading schemes aimed at converting co-processing products into synthetic crude oils suitable as feedstocks for conventional refineries.

In addition, the technique was extended to monitor the fate of nitrogen and oxygen during co-processing.

The isotope mass balance technique demonstrated that secondary upgrading increased the coal-derived carbon of co-processing liquids from 19 per cent to 27 per cent.

Preliminary measurements of the ratio of ^{15}N to ^{14}N revealed a two or three per cent difference for Alberta coals versus bitumen. This suggests that a viable analytical technique is possible.

This year, the study began to include measurements of hydrogen isotope effects. It was found that partitioning of hydrogen isotopes did occur in co-processing products, and an investigation was begun to determine the cause.

Meanwhile, researchers began using the technique fairly routinely to analyse the products of several co-processing experiments.

Publications

Ohuchi, T., J.G. Steer, K. Muehlenbachs and D. Carson. 1987. The Influence of Iron Based Catalyst on Coal Solubilization as Determined by ^{13}C Mass Balance Calculations. Proceedings of the 1987 International Conference on Coal Science, Maastricht, The Netherlands.

Steer, J.G., T. Ohuchi and K. Muehlenbachs. 1987. Efficacy of Coal-Bitumen Co-processing as Determined by Isotopic Mass Balance Calculations. Fuel Processing Technology. 15: 429-438.

Muehlenbachs, K., J.G. Steer, A. Hogg, T. Ohuchi and G. Beaulieu. 1988. Natural Variations of ^{13}C Abundance in Coal and Bitumen as a Tool to Monitor Co-processing. Proceedings of the 195th American Chemical Society National Meeting and 3rd Chemical Congress of North America, Toronto, Ontario.

Ohuchi, T., M. Bombin, J. Wilson and K. Muehlenbachs. 1988. Catalytic Hydrotreatment of the Products from the First Stage of Coal/ Bitumen Co-processing. Proceedings of the 38th Canadian Chemical Engineering Conference, Edmonton, Alberta.

Molecular Interactions Between Heavy Oil and Coal Species During Co-processing

UNIVERSITY OF CALGARY (P. CLARK), CALGARY

Heavy oils used in coal/bitumen co-processing schemes are rich in asphaltenic material and reactive sulphur compounds. These oils contain three to six weight per cent sulphur combined in a multitude of compounds. These compounds are likely to react with the radical species produced when coal is solubilized, which could result in undesirable products. Therefore, the objective of this project is to study these reactions and determine which process conditions avoid or minimize the formation of unwanted substances.

Although Alberta heavy oils contain a wide array of sulphur compounds, they can be classified in three main types: aliphatic thioethers, aromatic thioethers and condensed aromatic sulphur heterocycles. Chemicals representing each class were reacted with three chemicals having molecular structures commonly found in coal, namely hexadecane, naphthalene and tetralin. These reactions were carried out in a small (300 ml) autoclave, with or without hydrogen.

Thus far, it was observed that aliphatic thioethers are particularly reactive and, in the absence of an adequate hydrogen supply, lead to a variety of condensed thiophene derivatives when reacted with coal components. These products are difficult to upgrade in subsequent processing. Also, aromatic thioethers and benzothiophenes are less reactive and show little interaction with aliphatic and aromatic components of coal. Considerable desulphurization of these compounds occurred when a hydroaromatic chemical such as tetralin was present. Some coal components undergo a series of cracking reactions, which are desirable, but aromatic compounds undergo undesirable coupling reactions. Process conditions that include hydrogen donors or gaseous hydrogen inhibit coupling.

Hydroprocessing of Coal-Derived Liquids

UNIVERSITY OF ALBERTA (I.G. DALLA LANA), EDMONTON

When coal is liquefied to produce a synthetic crude oil, a wide variety of hydrocarbons is produced. The chemical structures of some of these products are such that they must be altered by subsequent hydrogenation reactions, otherwise the synthetic crude oil cannot be processed in existing oil refineries. Similarly, any sulphur-containing or nitrogen-containing molecules must be hydrogenated to remove these atoms.

To obtain desirable liquids that can be converted into valuable fuels in oil refineries, it is necessary to understand the chemical changes taking place when coal liquids are hydroprocessed. However, the complex array of chemicals comprising these products makes it virtually impossible to describe individual reactions. Therefore, functional group analysis (described in last year's annual review) is being used in this project to follow the effects of various hydroprocessing conditions on the amount of sulphur and nitrogen present in the hydroprocessed products.

A coal-derived liquid, produced from liquefaction studies at the Alberta Research Council, was obtained and characterized by functional group analysis. This feedstock was hydroprocessed in the presence of four catalysts to determine the effects of catalyst and temperature on the reaction chemistry. More than 20 reactor runs were completed.

At year-end, chemical analyses, thermogravimetric analysis and interpretation of the results were under way.

Liquefaction of Coal With Natural Gas

UNIVERSITY OF ALBERTA (M.R. GRAY), EDMONTON

One of the drawbacks of conventional coal liquefaction processes is that they depend on the use of expensive hydrogen. In some processes, hydrogen production can account for one-third of the total operating costs.

In this project, an alternative approach is being tried. Instead of producing hydrogen from natural gas, which is commonly done now in Alberta, natural gas (methane) is being used directly as the hydrogenation agent.

In laboratory investigations using a specially designed micro-reactor, liquefaction of Highvale subbituminous coal was carried out using tetralin as a donor solvent and either methane or hydrogen as the hydrogenation gas. Runs with argon, an inert gas, were made to provide baseline conditions. For comparison, runs were also made with well-characterized Illinois #6 bituminous coal. All experiments were conducted at 450°C and 19 to 24 MPa, with or without Fe_2O_3 catalyst. The toluene-soluble fraction of the reaction products was used as a measure of the conversion rate.

This work showed that natural gas is an active hydrogenation agent for coal liquefaction. When the Fe_2O_3 catalyst was present, the conversion to toluene-soluble products was higher or at least equal to that from hydrogen gas liquefaction. Also, liquefaction with natural gas produces more alkylated aromatic compounds and C_2-C_5 gases than hydrogen liquefaction. This could lead to greater amounts of "light ends."

It was concluded that substitution of natural gas for hydrogen could reduce the cost of producing liquid fuels and petrochemicals from coal.

Supercritical Gas Extraction of Coal

UNIVERSITY OF ALBERTA (N. BERKOWITZ), EDMONTON

In earlier work by this researcher, supercritical[1] water or, in some experiments, supercritical water plus carbon monoxide, was used to extract hydrocarbon material from coal. The technique relies on the fact that the vapour pressures of the thermally generated heavy "liquid" coal components are enhanced greatly when they are contacted with a compressed gas. When carbon monoxide is present, an internal shift reaction can provide hydrogen that simultaneously affects some upgrading of the extracted material.

Conversions to toluene-soluble "primary liquids" (plus co-produced water and gas) ranged from as high as 50 weight per cent in the case of lignite to 35 weight per cent for high-volatile bituminous coal.

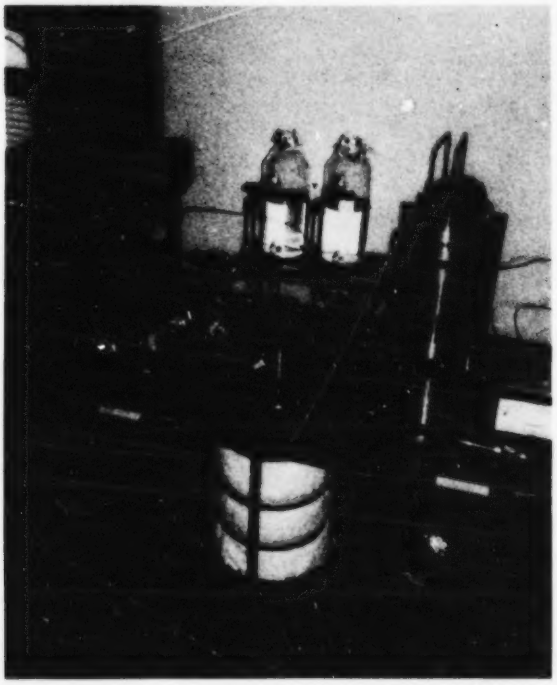
Because extraction with supercritical water could prove particularly useful for processing subbituminous coals that do not respond well to low-temperature carbonization or flash pyrolysis, a new study was initiated in 1986. It is focusing on a representative suite of Alberta coals. As before, the experimental procedure involves continuous extraction in a 1 L stirred autoclave at 400-425°C at pressures between 14 and 21 MPa.

[1]Critical temperature is the temperature above which a gas cannot be liquefied by pressure alone.

Thus far, it was found that yields were 25 per cent higher when carbon monoxide and supercritical water were used than when supercritical water alone was used. Also, an increase in the yield can result when an iron-based catalyst, such as iron oxide, is used. Significantly, the incremental yields were almost entirely composed of light hydrocarbons. Also, it has been observed that carbon monoxide tends to reduce the formation of water from oxygen-bearing functional groups in the coal.

Publication

Berkowitz, N. and J. Calderon. 1987. On "Partial" Coal Conversion by Extraction with Supercritical H_2O. Fuel Processing Technology. 16: 245-256.



Laboratory experiments using the apparatus shown here are under way to extract hydrocarbon liquids from coal.

Distributed Chemical and Physical Properties of Coal

UNIVERSITY OF ALBERTA (P.J. CRICKMORE), EDMONTON

Depending on the purpose, analytical investigations of coal can be divided into two groups: (1) those that attempt to extract minute details about particular components and properties; and (2) those that aim to relate generalized properties of coal to certain behavioural characteristics to provide a simple method of making predictions about those characteristics. This project represents the latter group.

It is based on the premise that chemical and physical properties of coal are spatially distributed, and a statistical analysis of these distributions can lead to predictions about coal behaviour in combustion, liquefaction or gasification processes, for example. Furthermore, it is believed that these distributions, whether on a large scale (such as in a coal seam) or a molecular scale, are not independent of each other.

In this project, fractal analysis is being used to derive relationships between underlying distributions of coal attributes and observed chemical or physical properties.

Following a literature review on the subject, an examination was begun of coal-derived liquids. Asphaltene content and molecular weight distributions were tracked and compared with other chemical and physical properties. Also, the adsorption of various gases on coal was studied as a potential method for establishing correlations between coal characteristics and processing behaviour.

Thus far, tentative correlations have been established between processing behaviour and coal rank, as well as the chemical and physical heterogeneity of the coal.

A possible measure of chemical heterogeneity is a fractal dimension arising from the low coverage adsorption of a single vapour on a coal. Physical heterogeneity might be measured by a second fractal dimension arising from the variation in the surface area affected by several vapours as they adsorb onto the coal surface.

Sulphur Isotope Studies of Coal

UNIVERSITY OF CALGARY (R.H. KROUSE), CALGARY

By measuring the various sulphur isotope compositions of naturally occurring, sulphur-containing substances, scientists are gaining a better understanding of the processes that formed marine sediments and fossil fuels.

In the past, sulphur isotope analyses tended to be conducted on total sulphur in a specimen or extracts using different solvents. In the current study, sulphur isotope techniques were used to identify and quantify the various forms in which sulphur occurs in coals. This is important because it relates to the methods used to remove sulphur from coal and to the analysis of liquids produced by coal conversion processes.

In previous work, the researchers developed a non-isothermal, pyrolysis-stable isotope technique to study forms of sulphur (and other elements) in fossil fuels. The technique involves heating a substance in a quartz reactor and analysing the evolved gases using continuous nitrogen purging. For sulphur studies, the evolved gas is hydrogen sulphide (H_2S).

In this project, coals from several Canadian sources - including low-sulphur Alberta coal and high-sulphur coal from Nova Scotia - were analysed by the pyrolysis-stable isotope technique and other methods, including Kiba Extraction, that was claimed to be capable of distinguishing between pyritic and sulphatic forms of sulphur. A critical assessment of the Kiba technique using sulphur isotope labelling revealed this claim to be overly optimistic.

After a more cost-effective quartz reactor was designed and a computer-based temperature controller developed, several samples of a control coal containing two weight per cent sulphur were pyrolysed to ascertain the reproducibility of the method. It was found that reproducibility was variable, apparently because of sample inhomogeneity. H_2S recovery was improved, however, by using flush gases containing hydrogen. They included water, methane and a mixture of helium and hydrogen. The helium/hydrogen mixture subsequently became the standard flush gas for the remaining experiments.

Coal samples containing minimal amounts of inorganic sulphur showed differences in H_2S evolution that could be related to coal rank. This behaviour in the sulphur isotope data can be interpreted in terms of the relative stabilities of various organic sulphur structures.

Magnetic and Electric Properties of Alberta Coals

UNIVERSITY OF CALGARY (H.A. BUCKMASTER), CALGARY

In this project, sophisticated analytical procedures are being used to investigate coal on a molecular scale. Information about the electronic structure of atoms and molecules, and the bonds formed between various components of coal, is being obtained by Continuous Wave Electron Paramagnetic Resonance (CWEPR), Electron Spin Echo (ESE) and Pulse Field-Sweep EPR analyses. This is expected to provide useful insights about free radical reactions that occur when coal is converted to liquid hydrocarbons. These reactions have also been implicated in the spontaneous combustion of coal.

Last year, a temperature controller, used to heat coal samples during EPR analysis, was designed and constructed. Also, a 2 GHz ESE spectrometer was assembled and a pioneering dynamic 9 GHz CWEPR study of selected Alberta coals and coal macerals was completed. The effect of various preliminary treatments, as well as exposure to moisture and air while the sample was heated to spontaneous combustion temperature, was studied. The influence of maceral and mineral content was also investigated.

The investigations revealed information about the role of water vapour in determining the susceptibility of coals to spontaneous combustion, and a better understanding of the magnetic and electrical properties of coals was achieved. At year-end, the project final report was being written.

Distribution of Oxygen Forms in Western Canadian Low-Rank Coals

UNIVERSITY OF ALBERTA (N. BERKOWITZ), EDMONTON

It is generally conceded by coal scientists that the chemical properties and physical behaviour of low-rank coals are largely determined by the reactive oxygen content, which can account for 75 to 90 per cent of the total oxygen content. Also, this reactive oxygen is to be found in phenolic hydroxyl (–OH), carboxyl (–COOH), carbonyl (=CO) and ether (–O) groups, while unreactive oxygen exists mostly in heterocyclic combinations.

However, there is considerable uncertainty about the relative abundance of individual reactive oxygen groups in low-rank coals. Therefore, the objective of this project is to measure the

concentrations and thermal stabilities of the dominant oxygen forms in a suite of Alberta bituminous and subbituminous coals. It is anticipated that this investigation may reveal an explanation for the dissimilar behaviour of coals that appear outwardly to be similar. For example, it is known that coals with virtually identical elemental and petrographic compositions will sometimes display very different pyrolytic behaviour and respond very differently to hydrogenation and solubilization in liquefaction schemes.

This year, the concentration of reactive oxygen groups was measured and preliminary data regarding the thermal stability of –COOH and –OH were obtained.

Publications

Berkowitz, N., J. Calderon and A. Liron. 1988. Fuel. 67: 627, 1017, 1139.

Takeuchi, M. and N. Berkowitz. Fuel. In press.

Electrolysis of Coal Slurries in New Environments

UNIVERSITY OF CALGARY (V.I. BIRSS), CALGARY

Research studies in several laboratories have shown that hydrogen is readily and inexpensively produced when acidic coal slurries are electrochemically oxidized. Furthermore, other gases of commercial importance, such as carbon monoxide and carbon dioxide, can be produced in a pure state.

These findings were confirmed in an earlier study by this investigator (reported in last year's annual report) in which coals originating from four mines (Highvale, Coal Valley, Vesta and Bow City) were pulverized and slurried in a mixture of sulphuric acid and ferrous sulphate. The slurries were exposed to an electric current both at room temperature and 90°C to produce hydrogen and various oxidized coal products.

In decreasing order, the electrochemical activity was found to be Highvale, Coal Valley, Vesta and Bow City.

This research work resulted in several new methods of regenerating the coal surface to allow high reaction rates over oxidation periods extending up to 25 hours.

Electrochemical oxidation was also carried out in acetic acid slurries. Higher reaction rates and concentrations of low molecular weight organic compounds were observed, but less carbon dioxide was produced than in sulphuric acid slurries. Also, the use of certain chemicals in place of ferrous sulphate to mediate the coal oxidation reaction resulted in rate constants that were 100 times higher than with iron.

The project demonstrated that electrochemical conversion of coal to commercially useful products is a promising technology worthy of further development.

Consequently, a new project was begun this year. Instead of sulphuric acid, it will use the following: aqueous organic solutions of acetic, formic and oxalic acids; aqueous alkaline solutions having a pH of 8 to 12; and aqueous/non-aqueous solvent mixtures, all containing various reduction/oxidation (redox) mediators. The purpose in using these new reaction media is to provide product selectivity and high reaction rates. This could represent an important step toward a new process for liquefying coal.

Thus far, it was learned that oxalic acid is not suitable for coal oxidation. Experiments were under way with solutions of other organic acids and aqueous/non-aqueous solutions.

Project Expenditures

Table 1: Funding Contributions to Approved Projects by Year ($)

Project Title	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	Projected Future Funding	Total
Coal-to-Ontario														
Thick Seam Extraction and Continuous Haulage Mining Demonstration	-	-	-	-	-	-	-	-	-	-	-	291 773	2 100 195	2 391 968
Air-Sparged Hydrocyclone (A.S.H.)	-	-	-	-	-	-	-	-	-	-	-	41 577	86 412	127 989
HYDROSIZER for Fine Coal Recovery from Tailings	-	-	-	-	-	-	-	-	-	-	-	21 000	60 000	81 000
Tailings Reclamation	-	-	-	-	-	-	-	-	-	-	-	3 649	44 099	47 748
Total – Coal-to-Ontario	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**357 999**	**2 290 706**	**2 648 705**
Coal Utilization														
Enhanced Oil Recovery														
Fuel Options for Enhanced Oil Recovery	-	-	-	-	-	-	-	-	15 000	-	-	-	-	15 000
Coal Use in Enhanced Oil Recovery	-	-	-	-	-	-	-	-	-	17 995	13 777	-	-	31 772
Coal-Fired Steam Injection Boiler	-	-	-	-	-	-	-	-	-	-	28 619	110 205	-	138 824
Application of the LNS Burner to an Oil Field Steam Generator	-	-	-	-	-	-	-	-	-	-	-	22 460	-	22 460
LNSB Steam Generator Demonstration	-	-	-	-	-	-	-	-	-	-	-	292 266	2 119 000	2 411 266
Subtotal – Enhanced Oil Recovery	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**15 000**	**17 995**	**42 396**	**424 931**	**2 119 000**	**2 619 322**
Gasification														
Fluidized Bed Gasification of Highvale Coal	-	-	-	-	-	-	-	-	-	-	64 201	-	-	64 201
Economics of Coal Gasification	-	-	-	-	-	-	-	-	-	-	10 045	-	-	10 045
Subtotal – Gasification	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**74 246**	**0**	**0**	**74 246**
Liquefaction/ Co-processing														
Coal Liquefaction Study	-	-	-	151 864	-	-	-	-	-	-	-	-	-	151 864
Coal Liquefaction Feasibility Study	-	-	-	-	-	-	-	90 553	-	-	-	-	-	90 553
PYROSOL Process Review	-	-	-	-	-	-	-	-	7 006	-	-	-	-	7 006
PYROSOL Process Development	-	-	-	-	-	-	-	-	-	2 282 650	603 461	630 249	1 450 205	4 966 565
Coal/Heavy Oil Co-processing Strategy for Alberta - Phase 1	-	-	-	-	-	-	-	-	-	-	-	-	5 556	5 556
Subtotal – Liquefaction/ Co-processing	**0**	**0**	**0**	**151 864**	**0**	**0**	**0**	**90 553**	**7 006**	**2 282 650**	**603 461**	**630 249**	**1 455 761**	**5 221 544**
Emission Control														
Sorbent Injection Study	-	-	-	-	-	-	-	-	-	-	-	15 000	-	15 000
Subtotal – Emission Control	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**15 000**	**0**	**15 000**

Project Expenditures (continued)

Project Title	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	Projected Future Funding	Total
Combustion														
Low NOxSOx Burner	-	-	-	-	-	-	-	-	-	50 028	-	-	-	50 028
Prediction of Coal Combustibility	-	-	-	-	-	-	-	-	83 359	56 463	7 594	-	-	147 416
Combustion of Agglomerated Coal	-	-	-	-	-	-	-	2 061	22 950	8 325	-	-	-	33 336
IEA Coal Combustion Science	-	-	-	-	-	-	-	-	101 619	184 708	146 368	32 869	-	465 564
Conversion from Oil to Coal Water Fuel	-	-	-	-	-	-	-	-	26 093	9 283	-	-	-	35 376
IEA Coal Combustion Science, Extension	-	-	-	-	-	-	-	-	-	-	-	-	200 000	200 000
Subtotal – Combustion	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2 061**	**234 021**	**308 807**	**153 962**	**32 869**	**200 000**	**931 720**
Total – Coal Utilization	**0**	**0**	**0**	**151 864**	**0**	**0**	**0**	**92 614**	**256 027**	**2 609 452**	**874 065**	**1 103 049**	**3 774 761**	**8 861 832**
Transportation														
Coal Slurry Pipeline Research	-	-	-	-	-	-	114 903	150 333	22 717	-	-	-	-	287 953
Coal Market Access Model Study	-	-	-	-	-	-	-	-	-	-	69 846	4 125	-	73 971
Coal-Oil Slurry Pipelining	-	-	-	-	-	-	-	-	-	-	204 331	455 578	-	659 909
Coal Slurry Technology	-	-	-	-	-	-	-	-	-	-	25 576	22 411	474 442	522 429
Total – Transportation	**0**	**0**	**0**	**0**	**0**	**0**	**114 903**	**150 333**	**22 717**	**0**	**299 753**	**482 114**	**474 442**	**1 544 262**
Coal Production														
Processing														
Froth Flotation Study at Coal Valley	-	-	-	-	-	-	-	-	-	-	29 237	-	-	29 237
Electrocoagulation	-	-	-	-	-	-	-	-	-	-	-	15 046	-	15 046
Subtotal – Processing	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**29 237**	**15 046**	**0**	**44 283**
Upgrading														
Agglomeration of Low-Rank Alberta Thermal Coals	-	-	-	-	-	-	136 754	-	-	-	-	(5 969)	-	130 785
Coal Beneficiation Process	-	-	-	-	-	-	-	68 546	153 438	595 072	75 330	23 461	-	915 847
Agglomeration for Beneficiation	-	-	-	-	-	-	-	-	18 444	31 328	-	-	-	49 772
Coal Agglomeration Process Development	-	-	-	-	-	-	-	-	-	-	35 000	35 000	17 500	87 500
Agglomeration of Coking Coal	-	-	-	-	-	-	-	-	-	-	90 000	-	-	90 000
Subtotal – Upgrading	**0**	**0**	**0**	**0**	**0**	**0**	**136 754**	**68 546**	**171 882**	**626 400**	**200 330**	**52 492**	**17 500**	**1 273 904**
Spontaneous Combustion														
Spontaneous Combustion of Thermally Treated Coal	-	-	-	-	-	-	-	-	-	-	-	25 503	-	25 503
Subtotal – Spontaneous Combustion	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**25 503**	**0**	**25 503**
Geotechnical Mining														
Surface Geophysics	-	-	-	-	-	-	-	96 915	112 053	124 500	-	-	-	333 468
VLF Geophysical Methods in Coal Exploration	-	-	-	-	-	-	-	4 426	10 420	-	-	-	-	14 846
Footwall Anchoring	-	-	-	-	-	-	-	-	-	81 246	57 853	-	-	139 099
Downhole Geophysical Characterization of Overburden	-	-	-	-	-	-	-	-	-	30 667	44 099	104 500	-	179 266

Project Title	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	Projected Future Funding	Total
In-Seam Coal Characterization	-	-	-	-	-	-	-	-	-	93 111	143 713	-	-	236 824
Geophysical Techniques for Foothills and Mountains	-	-	-	-	-	-	-	-	-	-	-	73 835	212 500	286 335
Subtotal – Geotechnical Mining	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**101 341**	**122 473**	**329 524**	**245 665**	**178 335**	**212 500**	**1 189 838**
Total – Coal Production	**0**	**0**	**0**	**0**	**0**	**0**	**136 754**	**169 887**	**294 355**	**955 924**	**475 232**	**271 376**	**230 000**	**2 533 528**
Other Projects														
Coal Technology Information Centre	-	-	-	-	-	143 753	114 830	123 537	189 000	-	-	-	-	571 120
Combustion Program Planning	-	-	-	-	-	-	-	-	39 612	18 991	18 000	-	-	76 603
CTIC Review	-	-	-	-	-	-	-	16 997	-	-	-	-	-	16 997
Data Gathering for Research Planning	-	-	-	-	-	-	-	-	10 784	41 212	-	-	-	51 996
Preparation and Upgrading Assistance to AOCRT	-	-	-	-	-	-	-	-	-	705	41 295	-	-	42 000
Fine Coal Technical Assistance	-	-	-	-	-	-	-	-	-	-	2 308	-	-	2 308
Coal Production Program Planning	-	-	-	-	-	-	-	-	-	-	-	36 750	20 000	56 750
Coal Utilization Program Planning	-	-	-	-	-	-	-	-	-	-	-	38 808	45 000	83 808
Total – Other Projects	**0**	**0**	**0**	**0**	**0**	**143 753**	**114 830**	**140 534**	**239 396**	**60 908**	**61 603**	**75 558**	**65 000**	**901 582**
Institutional Programs														
Alberta Research Council														
Combustion														
Combustion Characteristics of Alberta Coals	-	-	-	-	-	-	-	-	97 849	91 121	-	-	-	188 970
Combustion Process Research	-	-	-	-	-	-	-	-	25 215	125 000	-	-	-	150 215
Combustibility of Agglomerates	-	-	-	-	-	-	-	-	-	14 156	-	-	-	14 156
Influence of Porosity on Combustion	-	-	-	-	-	-	-	-	-	-	84 000	-	-	84 000
Combustibility of Upgraded Alberta Coals	-	-	-	-	-	-	-	-	-	-	115 000	-	-	115 000
Effect of Blending on Combustibility of Dissimilar Alberta Coals	-	-	-	-	-	-	-	-	-	-	36 000	-	-	36 000
Combustion Properties of Alberta Coals and Chars	-	-	-	-	-	-	-	-	-	-	-	150 000	-	150 000
Subtotal – Combustion	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**123 064**	**230 277**	**235 000**	**150 000**	**0**	**738 341**

Project Expenditures (continued)

Project Title	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	Projected Future Funding	Total
Gasification														
Gasification of Western Canadian Coals	-	-	-	-	-	-	-	-	-	38 500	-	-	-	38 500
Gasification Process Research	-	-	-	-	-	-	-	-	-	12 207	72 154	(401)	-	83 960
Gasification Properties of Alberta Coals	-	-	-	-	-	-	-	-	-	34 957	130 000	-	-	164 957
Gasification Behaviour of Alberta Coals	-	-	-	-	-	-	-	-	-	5,466	179 850	-	-	185 316
Gasification Laboratory Facilities	-	-	-	-	-	-	-	-	-	-	160 000	-	-	160 000
Devolatilization Properties of Alberta Coals	-	-	-	-	-	-	-	-	-	-	-	150 000	-	150 000
Gasification Properties of Alberta Coals	-	-	-	-	-	-	-	-	-	-	-	190 000	184 000	374 000
Subtotal – Gasification	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**91 130**	**542 004**	**339 599**	**184 000**	**1 156 733**
Liquefaction/ Co-processing														
ENR/ARC Coal Conversion Research	2 055	-	37 412	1 182 372	3 135 406	4 158 527	3 034 865	2 085 164	706 548	-	-	-	-	14 342 349
New Liquefaction Processes	-	-	-	-	-	-	-	-	32 949	198 000	-	-	-	230 949
Liquefaction Process Improvement	-	-	-	-	-	-	-	-	51 059	-	-	-	-	51 059
Liquefaction Process Evaluation	-	-	-	-	-	-	-	-	26 191	51 600	-	-	-	77 791
Chemistry of Coal Liquefaction	-	-	-	-	-	-	-	-	84 232	121 000	303 672	5 753	-	514 657
Secondary Upgrading	-	-	-	-	-	-	-	-	-	-	182 671	329	-	183 000
Product and Process Characterization	-	-	-	-	-	-	-	-	-	-	-	218 156	60 000	278 156
Secondary Upgrading of Co-processing Products	-	-	-	-	-	-	-	-	-	-	-	172 000	-	172 000
Subtotal – Liquefaction/ Co-processing	**2 055**	**0**	**37 412**	**1 182 372**	**3 135 406**	**4 158 527**	**3 034 865**	**2 085 164**	**900 979**	**370 600**	**486 343**	**396 238**	**60 000**	**15 849 961**
Geology														
Alberta Coal Geology Project	-	-	-	-	-	-	-	-	-	147 000	553 000	499 761	460 000	1 659 761
Subtotal – Geology	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**147 000**	**553 000**	**499 761**	**460 000**	**1 659 761**
Total – Alberta Research Council	**2 055**	**0**	**37 412**	**1 182 372**	**3 135 406**	**4 158 527**	**3 034 865**	**2 085 164**	**1 024 043**	**839 007**	**1 816 347**	**1 385 598**	**704 000**	**19 404 796**
Coal Mining Research Company														
Processing														
Coal Preparation Research	39 845	183 315	312 815	492 675	612 060	803 189	835 845	1 188 731	224 014	-	-	-	-	4 692 489
Numerical Analysis of Process Yield Losses	-	-	-	-	-	-	-	-	56 000	19 795	-	-	-	75 795
Properties of Thermally Dried Coal	-	-	-	-	-	-	-	-	99 459	45 000	-	-	-	144 459

Project Title	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	Projected Future Funding	Total
Washery Optimization	-	-	-	-	-	-	-	-	-	93 876	127 102	-	-	220 978
Coal Comminution	-	-	-	-	-	-	-	-	-	54 466	-	-	-	54 466
Stabilization of Dried Coals	-	-	-	-	-	-	-	-	-	37 423	-	-	-	37 423
Advanced Processes for Low-Rank Coals	-	-	-	-	-	-	-	-	-	79 392	-	-	-	79 392
Moisture and Ash On-Stream Analyser	-	-	-	-	-	-	-	-	-	-	26 553	-	-	26 553
Recovery of Coal from Tailings	-	-	-	-	-	-	-	-	-	-	82 231	-	-	82 231
Westcoal Separator	-	-	-	-	-	-	-	-	-	-	-	24 898	-	24 898
Subtotal – Co-processing	**39 845**	**183 315**	**312 815**	**492 675**	**612 060**	**803 189**	**835 845**	**1 188 731**	**379 473**	**329 952**	**235 886**	**24 898**	**0**	**5 438 684**
Geotechnical/ Mining														
Coal Mining Research	14 692	67 595	115 347	181 640	225 662	296 129	358 220	278 838	417 439	-	-	-	-	1 955 562
Coal Mining in 2035	-	-	-	-	-	-	-	-	78 682	-	-	-	-	78 682
Potential of Geophysical Techniques in Coal Exploration	-	-	-	-	-	-	-	-	69 470	-	-	-	-	69 470
Geotechnical Properties of Overburden	-	-	-	-	-	-	-	-	71 501	-	-	-	-	71 501
Triaxial Test Development	-	-	-	-	-	-	-	-	-	103 503	-	-	-	103 503
Robotics for Mine Control	-	-	-	-	-	-	-	-	-	96 178	-	-	-	96 178
Mining 2035 Workshop	-	-	-	-	-	-	-	-	-	25 226	-	-	-	25 226
Non-Cable Vehicle Guidance	-	-	-	-	-	-	-	-	-	-	133 455	-	-	133 455
Lasers in Coal Mining	-	-	-	-	-	-	-	-	-	-	50 954	-	-	50 954
Geostatistics	-	-	-	-	-	-	-	-	-	-	40 958	-	-	40 958
Automated Machine Control for Optimized Mining (AMCOM)	-	-	-	-	-	-	-	-	-	-	-	197 222	-	197 222
Dragline Operations Monitor	-	-	-	-	-	-	-	-	-	-	-	40 225	-	40 225
Subtotal – Geotechnical/ Mining	**14 692**	**67 595**	**115 347**	**181 640**	**225 662**	**296 129**	**358 220**	**278 838**	**637 092**	**224 907**	**225 367**	**237 447**	**0**	**2 862 936**
Total – Coal Mining Research Company	**54 537**	**250 910**	**428 162**	**674 315**	**837 722**	**1 099 318**	**1 194 065**	**1 467 569**	**1 016 565**	**554 859**	**461 253**	**262 345**	**0**	**8 301 620**

Project Expenditures (continued)

Project Title	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	Projected Future Funding	Total
Grants Program														
Creep Characteristics of Coal	-	-	-	-	-	-	14 439	2 020	-	-	-	-	-	16 459
Analysis of Coal-Bearing Strata Near Cadomin	-	507	15 762	3 731	-	-	-	-	-	-	-	-	-	20 000
Coal Ash Monitoring System	-	13 555	24 185	25 130	8 763	-	-	-	-	-	-	-	-	71 633
Support Design for Underground Cavities in Weak Rock	132 154	-	-	-	-	-	-	-	-	-	-	-	-	132 154
Production of Activated Carbon	-	-	-	32 364	7 077	-	-	759	-	-	-	-	-	40 200
Beneficiation of Coal by Agglomeration in Pipelines	-	-	-	49 944	60 947	74 523	22 220	-	-	-	-	-	-	207 634
Reflective Seismic Investigation of Western Canadian Coalfields	-	-	-	-	35 668	17 760	3 564	-	-	-	-	-	-	56 992
Automedium Cyclones	-	-	-	-	22 929	34 842	37 940	-	-	-	-	-	-	95 711
Hydroprocessing of Coal-Based Liquids	-	-	-	-	-	45 593	34 463	4 880	-	-	-	-	-	84 936
Coal Conversion Waste Water Treatment	-	-	-	-	-	30 000	57 890	-	-	-	-	-	-	87 890
Supercritical Gas Extraction of Coal	-	-	-	-	-	30 611	31 208	5 473	-	-	-	-	-	67 292
Ground Movements in Coal Mines	-	-	-	-	-	-	-	-	11 469	14 031	-	-	-	25 500
Functional Group Analysis of Coal Liquids	-	-	-	-	-	-	-	-	30 515	49 793	10 692	-	-	91 000
Coal Conversion Waste Water Treatment	-	-	-	-	-	-	-	-	17 305	38 577	8 118	-	-	64 000
Electrolysis of Coal Slurries	-	-	-	-	-	-	-	-	26 655	65 588	20 757	-	-	113 000
3-D Structural Geometries	-	-	-	-	-	-	-	-	22 873	30 127	-	-	-	53 000
Isotopic Analysis of Co-processing Schemes	-	-	-	-	-	-	-	-	22 082	51 918	-	-	-	74 000
Supercritical Gas Extraction of Coal	-	-	-	-	-	-	-	-	-	27 588	45 617	9 071	-	82 276
Time-Dependent Behaviour of Coal Measure Rocks	-	-	-	-	-	-	-	-	-	15 288	19 745	4 967	-	40 000
Corrosion in Gasification Systems	-	-	-	-	-	-	-	-	-	50 871	43 069	460	-	94 400
Causes of Spontaneous Combustion of Western Canadian Coals	-	-	-	-	-	-	-	-	-	52 040	46 396	705	-	99 141
Seismic Modelling of Shallow Coalfields	-	-	-	-	-	-	-	-	-	24 723	7 720	37 096	-	69 539
Deformation and Progressive Failure of Open-Pit Highwalls	-	-	-	-	-	-	-	-	-	44	71 934	12 724	-	84 702

Project Title	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	Projected Future Funding	Total
Hydroprocessing of Coal-Derived Liquids	-	-	-	-	-	-	-	-	-	15 607	46 209	24 205	12 584	98 605
Activated Carbon from Coal	-	-	-	-	-	-	-	-	-	31 738	57 997	10 265	-	100 000
Distributed Chemical and Physical Properties of Coal	-	-	-	-	-	-	-	-	-	-	8 973	30 450	-	39 423
Sulphur Isotope Studies of Coal	-	-	-	-	-	-	-	-	-	-	25 119	38 081	-	63 200
Liquefaction of Coal with Natural Gas	-	-	-	-	-	-	-	-	-	-	29 404	6 346	-	35 750
Magnetic and Electric Properties of Alberta Coals	-	-	-	-	-	-	-	-	-	-	40 397	69 053	-	109 450
Isotopic Studies of Coal/Bitumen Co-processing Schemes	-	-	-	-	-	-	-	-	-	-	77 784	43 508	-	121 292
Particle Distribution in Slurry Flow Through Tees and Manifolds	-	-	-	-	-	-	-	-	-	-	-	53 222	45 500	98 722
A Thermodynamic Model for Spontaneous Combustion of Coal	-	-	-	-	-	-	-	-	-	-	-	54 567	45 592	100 159
Distribution of Oxygen Forms in Low-Rank Coals	-	-	-	-	-	-	-	-	-	-	-	21 068	19 500	40 568
Electrolysis of Coal Slurries in New Environments	-	-	-	-	-	-	-	-	-	-	-	48 497	11 503	60 000
Molecular Interactions During Co-processing	-	-	-	-	-	-	-	-	-	-	-	48 464	57 936	106 400
Co-processing of Coal and Bitumen with Molten Halide Catalysts	-	-	-	-	-	-	-	-	-	-	-	-	70 000	70 000
Combined Processing of Coal, Heavy Oil and Natural Gas	-	-	-	-	-	-	-	-	-	-	-	-	60 000	60 000
Total – Grants Program	**132 154**	**14 062**	**39 947**	**111 169**	**135 384**	**233 329**	**201 724**	**13 132**	**130 899**	**467 933**	**559 931**	**512 749**	**322 615**	**2 875 028**
Total – Coal	**188 746**	**264 972**	**505 521**	**2 119 720**	**4 108 512**	**5 634 927**	**4 797 141**	**4 119 233**	**2 984 002**	**5 488 083**	**4 548 184**	**4 450 788**	**7 861 524**	**47 071 353**

Figure 1: Research Expenditure on Approved Projects (excluding Coal Research Centre, Devon).

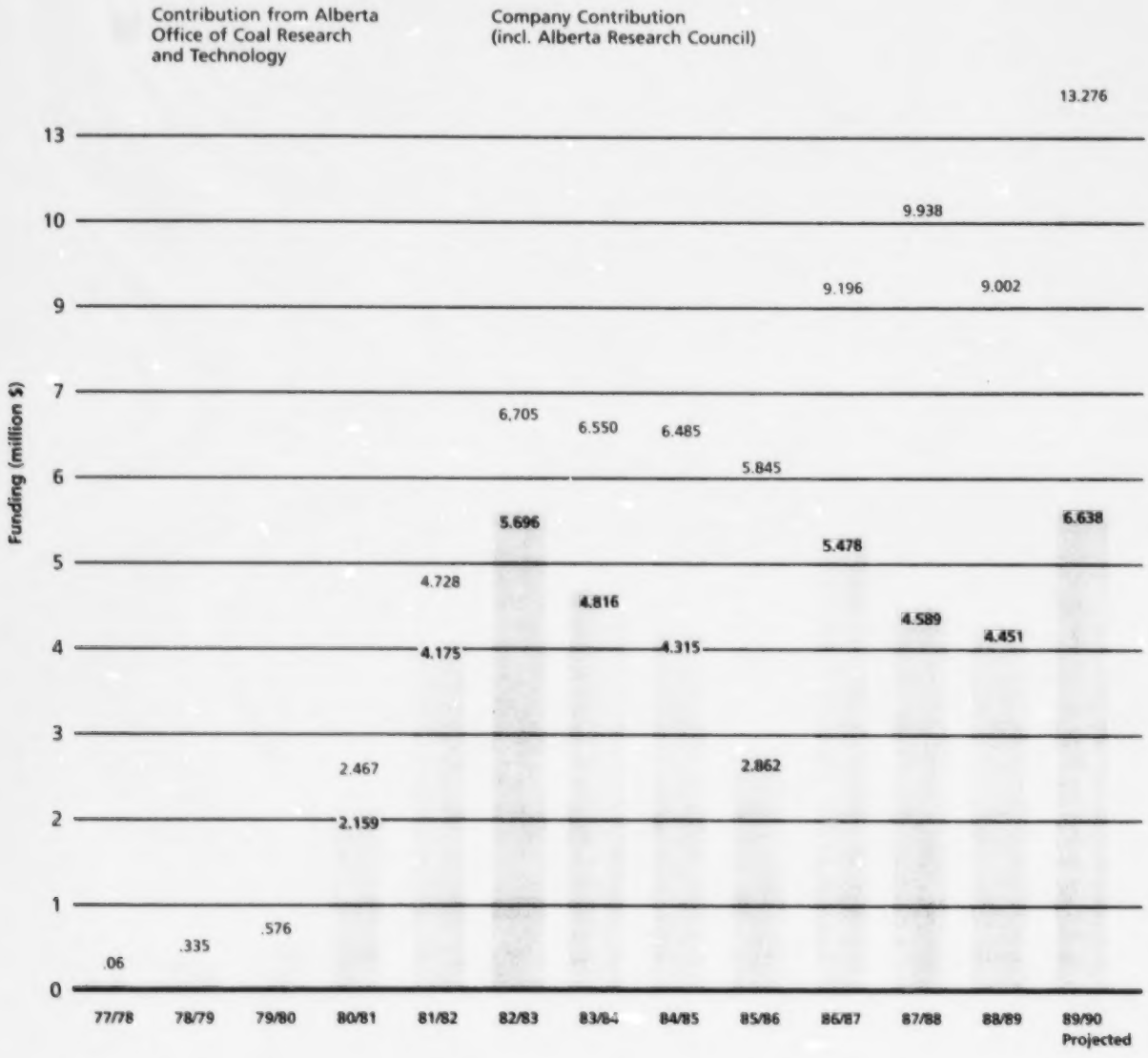
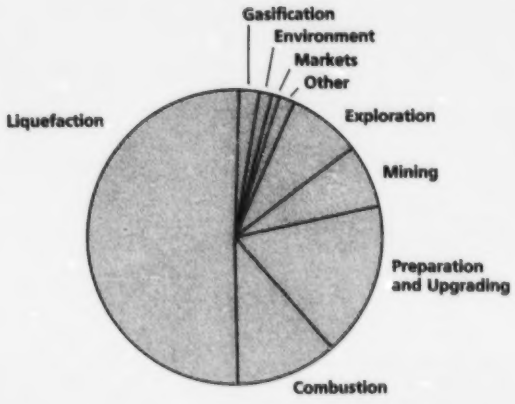
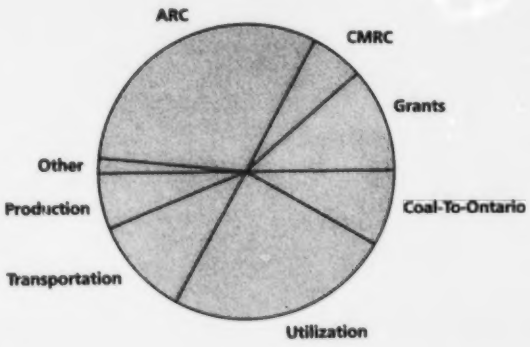


Figure 2: Distribution of Alberta Office of Coal Research and Technology Funding Contributions.

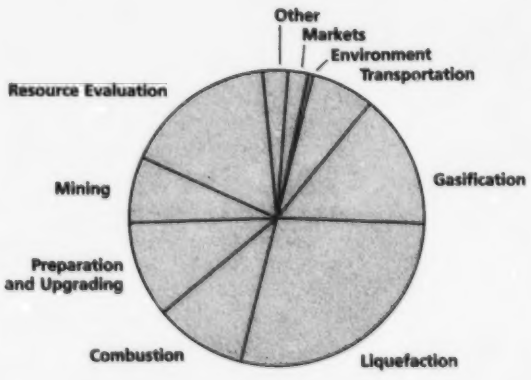
1986/87



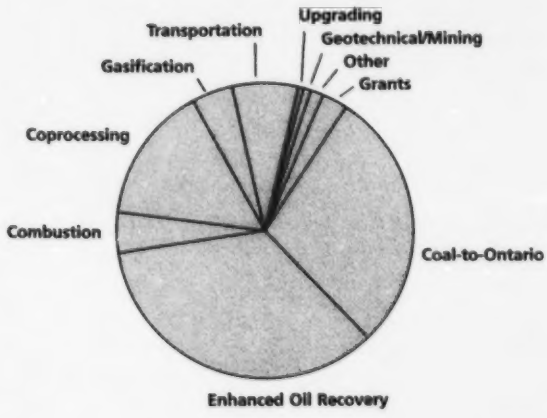
1988/89



1987/88



1989/90 (Projected)



Appendix

Projects Supported by the Alberta Office of Coal Research and Technology and Their Status

Western Coal-To-Ontario Program

Project	*Researcher*	*Status*
Thick-Seam Extraction and Continuous Haulage Mining Demonstration	Smoky River Holdings Ltd.	Continuing
Air-Sparged Hydrocyclone	Hydro Processing & Mining Ltd.	Continuing
HYDROSIZER for Fine Coal Recovery from Tailings	Obed Mountain Coal Company Limited	Continuing
Tailings Reclamation	Luscar Sterco (1977) Ltd.	Continuing
transCOM Co-ordinated Vendor Tests	Unocal Canada Limited	Continuing

Strategic Program

Projects completed or under way in this program are as follows:

Project	*Researcher*	*Status*
Surface Geophysical Coal Exploration	TransAlta Utilities Corporation and Others	Completed in 1986/87
Very Low Frequency Geophysical Methods in Coal Exploration	Smoky River Coal Limited	Completed in 1985/86
Downhole Geophysics	TransAlta Utilities Corporation and Others	Continuing
Surface Geophysical Techniques for Foothills and Mountain Coalfield Exploration	Esso Resources Canada Limited and Others	Continuing
Footwall Anchoring	Smoky River Coal Limited	Completed in 1987/88
Froth Flotation Study at Coal Valley	Luscar Sterco (1977) Ltd.	Completed in 1987/88
Electrocoagulation	Luscar Sterco (1977) Ltd. and Others	Continuing
Coal Beneficiation Process	Gulf Canada Resources Limited and Unocal Canada Limited	Continuing

Project	*Researcher*	*Status*
Coal Agglomeration Process Development	Alberta Research Council	Continuing
Agglomeration of Subbituminous Coal	Manalta Coal Ltd.	Completed in 1986/87
Agglomeration of Coking Coal	Smoky River Coal Limited	Completed in 1988/89
Spontaneous Combustion of Thermally Treated Coals	Unocal Canada Limited and Others	Completed in 1988/89
Smoky DENSECOAL Combustion Tests	Monenco Consultants Ltd.	Completed in 1985/86
Prediction of Coal Combustibility	Esso Resources Canada Limited	Completed in 1987/88
International Energy Agency Basic Coal Combustion Science	Netherlands Energy Research Foundation ECN	Continuing
Combustion of Agglomerated Coal	Luscar Ltd.	Completed in 1985/86
Fuel Options for Enhanced Oil	L.A. Smith Consulting and Development Ltd.	Completed in 1985/86
Coal Use in Enhanced Oil Recovery	Luscar Ltd. and Others	Completed in 1987/88
Low NO_x/SO_x Burner	TransAlta Utilities Corporation	Completed in 1986/87
Coal-Fired Steam Injection Boiler	Fording Coal Limited and Others	Completed in 1988/89
Application of the LNS Burner to an Oil Field Steam Generator	TransAlta Resources Investment Corporation and Others	Completed in 1988/89
LNS Burner Steam Generator Demonstration	TransAlta Resources Investment Corporation and Esso Resources Canada Limited	Continuing
Coal for Use in Enhanced Oil Recovery: Emission Control Technology	Esso Resources Canada Limited	Completed in 1987/88
Sorbent Injection Study	Alberta Power Limited and Others	Completed in 1988/89
Gasification of Western Canadian Coals	TransAlta Utilities Corporation and Others	Completed in 1986/87
Fluidized Bed Gasification of Highvale Coal	TransAlta Utilities Corporation and Others	Completed in 1987/88
Economics of Coal Gasification	Alberta Power Limited and Others	Completed in 1987/88

Project	*Researcher*	*Status*
Coal Liquefaction Feasibility Study	Contar Systems Engineering Ltd. and Others	Completed in 1984/85
Synthetic Fuels Program	SRI International	Completed in 1984/85
Economic Evaluation of Coal/Oil Co-processing	HRI Inc.	Completed in 1984/85
PYROSOL Process Review	Canadian Utilities Ltd. and Luscar Ltd.	Completed in 1985/86
PYROSOL Process Development	Canadian Energy Developments Inc.	Continuing
Coal Slurry Pipeline Research	Pembina Resources Ltd.	Completed in 1984/85
Coal Market Access Model	Trimac Consulting Services Ltd.	Continuing
Coal-Oil Slurry Pipelining	Unocal Canada Limited	Continuing
Coal/Oil/Natural Gas Transportation System	CERI Energy Research Ltd.	Completed in 1987/88
Coal Slurry Technology	Salzgitter Industriebau GmbH and Others	Continuing
Imported Steam Coal Demand	The Institute of Energy Economics (Japan)	Completed in 1984/85
Conversion from Oil to Coal-Water Fuels	Smoky River Coal Limited	Completed in 1985/86
Technical Information Needs	Crozier Information Resources Consulting Ltd.	Completed in 1985/86

Institutional Program

Coal Mining Research Company

Several research projects funded by the Office were carried out by the Coal Mining Research Company as follows:

Project	*Status*
Potential of Geophysical Techniques for Coal Exploration	Completed in 1985/86
In-Seam Coal Characterization	Completed in 1987/88
Geotechnical Properties of Overburden	Completed in 1985/86
Coal Mining Research	Completed in 1985/86
Triaxial Test Development	Completed in 1986/87
Coal Mining in 2035	Completed in 1985/86
Mining 2035 Workshop	Completed in 1986/87
Robotics for Mine Control	Completed in 1986/87
Non-Cable Vehicle Guidance	Completed in 1987/88
Lasers in Coal Mining	Completed in 1987/88
Geostatistics	Completed in 1987/88

Automated Machine Control for Optimized Mining (AMCOM)	Completed in 1988/89
Dragline Operations Monitor	Completed in 1988/89
Coal Preparation Research	Completed in 1985/86
Coal Comminution	Completed in 1986/87
Preparation and Upgrading Assistance	Completed in 1987/88
Washery Optimization	Completed in 1988/89
Moisture and Ash On-Stream Analyser	Completed in 1987/88
Numerical Analysis of Process Yield Losses	Completed in 1986/87
Advanced Processes for Low-Rank Coal	Completed in 1986/87
Properties of Thermally Dried Coals	Completed in 1986/87
Stabilization of Dried Coal	Completed in 1986/87
Recovery of Coal from Tailings	Completed in 1987/88
Fine Coal Cleaning	Completed in 1987/88
WESTCOAL Separator	Completed in 1988/89
Coal Production Program Planning	Continuing
Data Gathering for Research Planning	Completed in 1986/87

Alberta Research Council

Projects funded thus far at the Alberta Research Council have been concerned with coal combustion, coal gasification and conversion of coal to liquid fuels.

Project	*Status*
Combustion Process Research	Completed in 1986/87
Combustion Characteristics of Alberta Coals	Completed in 1986/87
Combustibility of Agglomerates	Completed in 1986/87
Combustion Program Planning	Completed in 1987/88
Influence of Porosity on Combustion	Completed in 1987/88
Combustibility of Upgraded Alberta Coals	Completed in 1987/88
Evaluation of Blending on Combustibility	Completed in 1987/88
Combustion Properties of Alberta Coals and Chars	Completed in 1988/89
Coal Utilization Program Planning	Continuing
Gasification Process Research	Completed in 1987/88
Gasification Properties of Alberta Coals	Completed in 1987/88
Gasification Behaviour of Alberta Coals	Completed in 1988/89
Gasification Laboratory Facilities	Completed in 1987/88
Devolatilization Properties of Alberta Coals	Continuing
Gasification Properties of Alberta Coals, II	Continuing
Liquefaction Process Improvements	Completed in 1985/86
New Liquefaction Processes	Completed in 1986/87
Liquefaction Process Evaluation	Completed in 1986/87
Chemistry of Coal Liquefaction	Completed in 1988/89
Secondary Upgrading	Completed in 1987/88
Secondary Upgrading of Co-processing Products	Completed in 1988/89
Product and Process Characterization	Continuing
Coal Utilization Program Planning	Continuing

Coal Research Grants Program

Since 1985, 25 projects have been initiated within the Coal Research Grants Program, of which nine were completed during 1988/89. These projects and their status are as follows:

Project	*Researcher*	*University*	*Status*
Structural Geometry of Imbricated Thrust Sheets	Dr. D.A. Spratt	University of Calgary	Completed in 1986/87
Ground Movements in Coal Mines	Dr. D.M. Cruden	University of Alberta	Completed in 1986/87
Seismic Modelling of Shallow Coalfields	Dr. D.C. Lawton	University of Calgary	Completed in 1988/89
Time-Dependent Behaviour of Coal Measure Rocks	Dr. R. Day	University of Calgary	Completed in 1988/89
Deformation and Progressive Failure of Open-Pit Highwalls	Dr. N.R. Morgenstern	University of Alberta	Completed in 1988/89
Particle Distribution in Slurry Flow Through Tees and Manifolds	Dr. J.H. Masliyah	University Of Alberta	Continuing
Causes of Spontaneous Combustion of Western Canadian Coals	Dr. F.W. Bachelor	University of Calgary	Completed in 1987/88
A Thermodynamic Model for the Spontaneous Combustion of Coal	Dr. R. Paul	University of Calgary	Continuing
Corrosion in Gasification Systems	Dr. W.J.D. Shaw	University of Calgary	Completed in 1987/88
Isotopic Studies of Coal/Bitumen Co-processing	Dr. K. Muehlenbachs	University of Alberta	Completed in 1986/87
Functional Group Analysis of Coal Liquids	Dr. M.R. Gray	University of Alberta	Completed in 1987/88
Supercritical Gas Extraction of Coal	Dr. N. Berkowitz	University of Alberta	Completed in 1988/89
Liquefaction of Coal with Natural Gas	Dr. M.R. Gray	University of Alberta	Completed in 1988/89
Isotopic Studies on Coal/Bitumen Co-processing Schemes	Dr. K. Muehlenbachs	University of Alberta	Completed in 1988/89
Hydroprocessing of Coal-Derived Liquids	Dr. I.G. Dalla Lana	University of Alberta	Continuing

Project	*Researcher*	*University*	*Status*
Molecular Interactions Between Heavy Oil and Coal Species During Co-processing	Dr. P.D. Clark	University of Calgary	Continuing
Activated Carbon From Coal	Dr. E.L. Tollefson	University of Calgary	Completed in 1987/88
Coal Conversion Waste-Water Treatment	Dr. S.E. Hrudey	University of Alberta	Completed in 1987/88
Electrolysis of Coal Slurries	Dr. V.I. Birss	University of Calgary	Completed in 1987/88
Distributed Chemical and Physical Properties of Coal	Dr. P.J. Crickmore	University of Alberta	Completed in 1988/89
Sulphur Isotope Studies of Coal	Dr. R.H. Krouse	University of Calgary	Completed in 1988/89
Magnetic and Electric Properties of Alberta Coals	Dr. H.A. Buckmaster	University of Calgary	Completed in 1988/89
Distribution of Oxygen Forms in Western Canadian Low-Rank Coals	Dr. N. Berkowitz	University of Alberta	Continuing
Electrolysis of Coal Slurries in New Environments	Dr. V.I. Birss	University of Calgary	Continuing

Persons wishing to receive future Office publications or requesting more information about Office projects and programs should contact:

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Alberta Coal: Energy for the World. 27 pages, August 1987.

Annual Review 1984/85, Alberta Office of Coal Research and Technology. 24 pages, 1985.

Annual Review 1985/86, Alberta Office of Coal Research and Technology. 26 pages, 1986.

Annual Review 1986/87, Alberta Office of Coal Research and Technology. 32 pages, 1988.

Annual Review 1987/88, Alberta Office of Coal Research and Technology. 62 pages, 1989.

An Economic Analysis of Coal Pipeline Systems. 6 pages, January 1987.

Opportunities to Use Coal in Enhanced Oil Recovery. 8 pages, May 1988.

Development of an Agglomeration Process to Beneficiate and Transport Alberta Coals. 14 pages, June 1988.

Gasification of Western Canadian Coals. 14 pages, June 1988.

Coal Research Centre, Devon. 10 pages, August 1988.

Co-processing Studies of Alberta Subbituminous Coals. 14 pages, December 1988.

Mathematical Modelling of Automedium Cyclones. 10 pages, January 1989.

The Technical Committee Approach to Coal Research. 6 pages, January 1989.

Advanced Coal Mining Techniques for Alberta. 10 pages, March 1989.

Some Combustion Studies of Alberta Coals. 13 pages, May 1989.

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Canadian Energy Developments Inc. ..... p 25
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